IN THE UNITED STATES DISTRICT COURT

UNITED STATES OF AMERICA and STATE OF LOUISIANA,	)	
PLAINTIFFS,	)	
V.	)	
	)	CIVIL ACTION NO.
DEFENDANTS.	)	

CONSENT DECREE

165113

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Attachment A: Settling Parties -- Owners of the Site

Attachment B: Other Settling Parties

Attachment C: Record of Decision

Attachment D: Statement of Work

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CONSENT DECREE

WHEREAS, the United States of America ("United States"), on behalf of the Administrator of the United States Environmental Protection Agency ("EPA") and the State of Louisiana ("Louisiana") on behalf of the Louisiana Department of Environmental Quality ("DEQ") have filed a complaint under Sections 106 and 107 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 ("CERCLA"), 42 USC §§ 9606, 9607 as amended by the Superfund Amendments and Reauthorization Act of 1986 ("SARA") and § 7003 of the Resource Conservation and Recovery Act ("RCRA"), as amended 42 USC § 9673; and the Louisiana Environmental Quality Act ("LEQA"), LSA R.S. 30:1051 et seq.; and the laws of the State of Louisiana.

WHEREAS, the complaint filed by the United States and Louisiana alleges that the defendants named in the

complaint and referred to herein as "Settling Parties" are persons within the meaning of CERCLA and RCRA who may be liable for the abatement or cost of abatement of any release or threat of release of hazardous substances from the Bayou Sorrel waste disposal site ("Site") and seek by their complaint to impose liability for the abatement of any such endangerment on the Settling Parties; and

WHEREAS, the Settling Parties and each of them deny the allegations in the complaint filed by the United States and Louisiana and further deny that any imminent and substantial endangerment or that any release or threat of release of any hazardous substance is presented by conditions at the Site and the Settling Parties and each of them further deny the need for and scope of additional response at the Site; and

WHEREAS, the Settling Parties and each of them deny responsibility for the disposal of materials at the Site and deny any legal or equitable liability under any statute, regulation, ordinance or common law for any response costs or damages caused by storage, treatment, handling or disposal activities or actual or threatened releases of materials at the Site; and

WHEREAS, after consultation with Louisiana, on November 14, 1986, EPA issued a Record of Decision ("ROD") which selected the appropriate remedial action for the Bayou

Sorrel waste disposal site ("Site"), which is, to the maximum extent practicable consistent with Section 121 of CERCLA as amended by SARA; the National Oil and Hazardous Substance Pollution Contingency Plan, 40 CFR Part 300 ("NCP"); and pertinent Environmental Protection Agency guidelines and policies; and

WHEREAS, the parties desire and intend hereby to protect public health, welfare and the environment from the release or threat of release of hazardous substances from the Site by the implementation of the remedial action set forth in this decree; and

WHEREAS, except as otherwise set forth in this Consent Decree, the United States and Louisiana intend to covenant not to sue, not to issue administrative orders, not to execute judgment against the Settling Parties for response costs and/or injunctive relief arising out of or with respect to the transportation, storage, treatment, handling, disposal or presence of materials or the release or threat of release of hazardous substances at the Bayou Sorrel Site for which members of the Settling Parties are responsible as long as the Settling Parties comply with their obligations under the Consent Decree; and

WHEREAS, it is the further intention of the parties to settle and compromise this litigation and the dispute

between them concerning the liability of the Settling Parties with respect to the Bayou Sorrel Site so as not to settle any claim, forego any right which they may have, covenant not to sue or release in any way any person other than the Settling Parties for liability arising under CERCLA, RCRA, or the laws of the State of Louisiana with respect to the Bayou Sorrel Site; and

WHEREAS, the parties intend that each of the members of the Settling Parties has the benefit of Section 113(f) of CERCLA to limit their liability to other parties, to seek contribution together with any other equitable or legal remedy which they may have from any person or entity not a party to this Consent Decree for costs incurred or relief with respect to the Bayou Sorrel Site in order to enable the Settling Parties to recover the full relief available to them at law or equity from all parties who may be liable for cost recovery and injunctive or other relief at the Bayou Sorrel Site; and

WHEREAS, to accomplish the objectives set forth in this Consent Decree the parties have agreed that it is in the public interest and in the interest of the parties for this case to be settled without protracted litigation, before the taking of any testimony, and without the adjudication of any fact or law; and

WHEREAS, each undersigned representative of the parties to the Consent Decree certifies that he or she is fully authorized to enter into the terms and conditions of this Consent Decree and to execute and legally bind such party to this document.

THEREFORE, it is ORDERED, ADJUDGED, AND DECREED as follows:

I. JURISDICTION

The Court has jurisdiction of this matter and of the parties consenting thereto. The parties agree not to contest the jurisdiction of the Court to enter this Consent Decree or in any subsequent action to enforce, modify or terminate it. The Original Joint Complaint filed by the Plaintiffs states a cause of action upon which, if the allegations were proved, relief can be granted. The parties agree and the Court finds that nothing herein constitutes any admission of fact or law.

II. PARTIES

The parties to this Consent Decree are:

1. The United States of America on behalf of the United States Environmental Protection Agency.

2. The State of Louisiana on behalf of the Louisiana Department of Environmental Quality.

3. The persons listed in Attachment A who are the owners of the Site, hereinafter referred to as "Owners." Owners are Settling Parties as defined herein.

4. The persons listed in Attachment B who are alleged to be persons who may be liable for the cost of response at the Site within the meaning of CERCLA. The persons listed in Attachment B are Settling Parties as defined herein.

III. SITE

Site Location and Description

The Site is located in Section 40, 41, 42, 43 and in Township 10 South, Range 10 East, in Iberville Parish, Louisiana, approximately 20 miles southwest of Baton Rouge, Louisiana, about six miles northwest of the town of Bayou Sorrel. The west border of the Site is bound by a man-made drainage feature called "Borrow River." About 100 yards west of Borrow River is the Atchafalaya Basin Protection Levee, while the north and east sides of the Site are bound by the Upper Grand River and Pat Bayou, respectively. Undeveloped swamp land is adjacent to the Site on the South. Access to

the Site from the north is along the unpaved levee road 14 miles south of its intersection with Interstate 10 at Ramah, Louisiana, while access from the south is along the same unpaved levee road six miles north of the town of Bayou Sorrel. The Upper Grand River provides barge access to the Site.

The Site is a "T" shaped, relatively flat parcel of land encompassing about 265 acres. Approximately 50 of the 265 acres were actually used for waste disposal. The waste disposal areas consist of four landfills including the spent lime cell and the crushed drum cell, four covered liquid waste ponds, and one land farm. All of the disposal areas have been covered with natural soils and contoured as part of judicial proceedings initiated by the Louisiana Department of Health and Human Resources against Cyril Hines, et al., for a closure of the Site in 1978 and 1979. These disposal areas are characterized by their slightly mounded soil caps which have scattered areas without vegetation. Pond 4 exhibits a very distinguishable soil cap. A 50-acre lake and one acre pond, probably former borrow pits, are situated along the north border of the Site.

Apart from the disposal areas, the Site is generally covered by dense brush and trees. The Site (particularly the south end) and surrounding areas can best be

described as having marshy bayou-type environment and are prone to periodic flooding and poor drainage.

Site History

The Site was and is owned by the Owners described in Paragraph II(3) and was operated by Environmental Purification Advancement Corporation as a chemical/industrial landfill from 1976 and 1978 in conjunction with Clean Land Air Water Corporation; and

The Site was closed by the operator pursuant to judicial proceedings initiated by the Louisiana Department of Health and Human Resources ("LDHHR") in 1978-1979 and overseen by LDHHR;

A group known as and referred to herein as the Bayou Sorrel Task Force ("BSTF"), in cooperation with the Owners, voluntarily conducted removal measures at the Site at their own expense, which measures consisted of repairing the clay cap over one pond and reseeding bare areas to prevent erosion, which measures were and are consistent with the remedial alternative selected in the ROD; and

In 1983-84, the BSTF voluntarily and independently conducted an investigative study of conditions at the Site and provided the study to the United States and Louisiana.

Among the purposes of the BSTF investigative study were the characterization of the extent and degree of soil, surface water and groundwater contamination at the Site; the determination of the potential for a release or threatened release of hazardous substances from the Site; critiquing and commenting on the Remedial Investigation and Feasibility Study ("RI-FS") conducted by the United States; and developing and evaluating cost effective remedial action alternatives for the Site which would adequately protect public health and the environment; and

The United States has undertaken a RI-FS of the Bayou Sorrel Site pursuant to the National Oil and Hazardous Substance Pollution Contingency Plan, 40 CFR 300 et seq. ("NCP"), the purpose of which was inter alia to characterize the extent and degree of soil, surface water and groundwater contamination at the Site; determine the potential for a release or threatened release of hazardous substances from the Site; and develop and evaluate cost-effective remedial action alternatives for the Site which would adequately protect public health, welfare and the environment; and

Prior to selection of the remedy the BSTF provided written and verbal comments to the United States, inter alia, about the RI-FS conducted by the United States, about Site conditions and about the need for additional remedial action at the Site. The United States considered the

BSTF investigative Site study and comments and utilized portions of them in selecting the remedial action alternative for the Site; and

In a Record of Decision ("ROD") issued on November 14, 1986 (Attachment C), EPA in consultation with Louisiana selected the appropriate remedial action that was, to the maximum extent practicable, consistent with Section 121 of CERCLA, as amended by SARA and the National Contingency Plan.

IV. BINDING EFFECT

This Consent Decree applies to and is binding upon the United States, the State of Louisiana and the Settling Parties, their officers, employees, agents, successors and assigns, and upon all persons or firms, subsidiaries, and corporations acting under, through, for or in active concert or participation with the parties in the performance of any obligations hereunder. The Settling Parties shall provide a copy of this Consent Decree to each contractor and subcontractor retained to perform work contemplated herein and condition each such contract on performance of the work in accordance with this Consent Decree.

V. OBLIGATIONS FOR THE REMEDIAL ACTION

A. The Settling Parties shall implement the remedial action described in the ROD (Attachment C), as more fully developed in the Statement of Work ("SOW", Attachment D). In determining what constitutes implementation, the more specific language of the SOW shall control. Attachments C and D are incorporated herein by reference and enforceable as part of this Consent Decree.

B. The Settling Parties shall appoint a representative ("Remedial Project Coordinator" or "RPC") pursuant to Section VII below, designated by them to act on their behalf to execute the remedial action.

C. The parties recognize and agree that implementation of the appropriate remedial action will be undertaken in two phases. During Phase I, the remedial design for construction of the remedial action selected in the ROD will be completed pursuant to the SOW. During Phase II, construction of the remedial action will be completed pursuant to the SOW. The Settling Parties agree to finance and implement Phase I and Phase II and to finance and perform the operation and maintenance approved hereunder which is set forth in the SOW.

D. Except as otherwise set forth in Sections VII(c) and XVI, and so long as the Settling Parties implement Phase I, Phase II and the operation and maintenance plan approved hereunder in accordance with the terms of the SOW and this decree, and so long as the remedial action is protective of human health and the environment, the United States and Louisiana agree they will not undertake any of the work and will not seek to have the Settling Parties undertake any response at the Site in addition to that required in the SOW.

E. In the event the United States and Louisiana determine that the Settling Parties have failed to implement the remedial action in accordance with the SOW, after thirty days' written notice to the Settling Parties of their determination (which shall specify the bases for such determination) and any dispute resolution which the parties may seek in accordance with Section XIX hereunder, the United States and Louisiana may perform any or all portions of the remedial action which remains incomplete. The Settling Parties shall be and remain liable for the cost of completing the remedial action and shall, consistent with the Dispute Resolution provisions of Section XIX hereunder, reimburse the Hazardous Response Trust Fund ("Superfund") for the cost of completing the remedial action within 90 days upon receipt of demand and provision to the Settling Parties of certification by the United States and Louisiana of the remedial action done and cost documentation for the remedial action done by the United

States and Louisiana. The Settling Parties shall have a right to review cost documentation prior to reimbursing the Superfund for the cost of completing the remedial action. The Settling Parties shall not be and are not liable hereunder to reimburse the Superfund for costs incurred for remedial action inconsistent with or beyond the scope of the SOW. The Settling Parties shall not be liable for any stipulated penalties hereunder for failure to comply with the terms of this Consent Decree from and after the receipt of notice from the United States and Louisiana of their determination that the Settling Parties have failed to perform the remedial action in accordance with the SOW and the United States' and Louisiana's intent to take over all or a portion of the work.

The Settling Parties shall have the right to seek dispute resolution within thirty days of receipt of the notice by the United States and Louisiana of their intent to take over all or a portion of the work. In any subsequent action by the United States and Louisiana under this paragraph for the cost of completing the remedial action, the Settling Parties shall have the burden of proving that costs claimed by the United States and Louisiana were for work inconsistent with or beyond the scope of the SOW.

F. Upon completion and approval of the Remedial Design (Phase I) and again upon completion and approval of

Phase II in accordance with the approved SOW, EPA and DEQ shall certify that the remedial action performed in completing Phase I and Phase II is in accordance with the requirements of CERCLA, the ROD, and the SOW, and is consistent with the NCP.

VI. WORK TO BE PERFORMED

A. The Settling Parties have selected a contractor qualified to conduct the remedial design and construction activities described in the SOW.

B. The Settling Parties have submitted and the United States and Louisiana have approved the SOW, and a schedule for initiation and completion of the remedial action as set forth in the SOW.

C. All work performed by the Settling Parties shall be done in accordance with the provisions and schedule contained in the SOW. The Settling Parties shall notify the United States and Louisiana within 15 days of completion of Phase II.

D. Within 105 days after the Settling Parties complete Phase II remedial action, the Settling Parties shall submit to the United States and Louisiana a remedial action report that includes a certification of completion from a registered professional engineer that the remedial action has

been completed in compliance with the terms of the SOW. The remedial action report shall include documentation of compliance with the terms of the Quality Assurance/Project Plan ("QA/PJP") and other conditions contained in the SOW.

E. Within 90 days of receipt of the operation, maintenance and monitoring plan, remedial action report, and certification of completion of the remedy, the United States and Louisiana shall provide written notice to the Settling Parties of its approval/disapproval of each of these items, and in the event that all are approved, shall certify that the remedial action is complete and that it satisfies CERCLA, the ROD, the SOW, and is consistent with the NCP.

F. Upon receipt of EPA's approval of the operation, maintenance, and monitoring plan, the Settling Parties shall implement the plan.

G. If during the term of this Consent Decree, a statistically significant increase of hazardous substances as defined in the Groundwater Statistics Plan ("increase") occurs, then:

1. Within 45 days of the confirmation of such increase, the Settling Parties will submit to EPA and DEQ for approval a plan to perform an evaluation and prepare an evaluation report to determine

whether the source of the increase is the disposal area. The evaluation plan will include a schedule for completion of the evaluation and submission of the evaluation report. EPA and DEQ have forty-five (45) days to review and approve or disapprove the plan. If EPA and DEQ disapprove the evaluation plan, they will notify the Settling Parties in writing and state the bases for such disapproval. Any such determination of disapproval will be subject to the Dispute Resolution provisions of Section XIX;

2. The Settling Parties will submit the evaluation report in accordance with the schedule contained in the approved evaluation plan. The evaluation report will consider all of the data obtained during the evaluation, and a copy of any such data will be provided to EPA and DEQ with the evaluation report. EPA and DEQ will have sixty (60) days to review the evaluation report and approve or disapprove the report. If EPA and DEQ disapprove the evaluation report, they will notify the Settling Parties in writing and state the bases for such disapproval. Any such determination of disapproval will be subject to the Dispute Resolution provisions of Section XIX;

3. Within 180 days of their receipt of a final determination, whether by dispute resolution or agreement, that the disposal area is the source of the increase, the Settling Parties will submit to EPA and DEQ a written report evaluating alternatives and a proposal for such additional response actions as may be necessary to maintain the remedy as consistent with the ROD, the SOW, Section 121 of CERCLA and the NCP. The report will include a schedule for development of a remedial design and a schedule for implementation of any such proposal. EPA and DEQ have ninety (90) days to review and approve or disapprove the proposal. If EPA and DEQ disapprove the report, they will notify the Settling Parties in writing and state the bases for such disapproval. Any such determination of disapproval will be subject to the Dispute Resolution provisions of Section XIX;

4. With thirty (30) days of a final determination of any specific additional response action that is necessary to maintain the remedy as consistent with the ROD, the SOW, Section 121 of CERCLA and the NCP, whether by dispute resolution or by agreement, the Settling Parties will initiate such response action and complete it in accordance with approved schedule.

The parties will request the Court to amend this Consent Decree to incorporate any modifications necessary to implement the agreed proposals of the Settling Parties.

Except for the 45-day period set forth in subparagraph VI.G.(1) and the 180-day period set forth in subparagraph VI.G.(3), the Settling Parties will not be liable for stipulated penalties or any other penalties or sanction for any activity arising under this paragraph until this Consent Decree has been modified by Court Order to reflect the results of any agreement or dispute resolution between the parties.

VII. PROJECT COORDINATOR

A. All work performed pursuant to this Consent Decree by the Settling Parties shall be under the direction and supervision of a Remedial Project Coordinator ("RPC") appointed by Settling Parties who shall be a qualified professional engineer or person otherwise qualified to conduct the activities to be performed hereunder. Upon their selection and prior to their undertaking any work at the Site, the Settling Parties shall notify EPA and DEQ in writing of the name of the RPC, and of the names and responsibilities of the contractors and principal subcontractors who will perform Phase I and Phase II. Upon request of the United States and Louisiana, the Settling Parties shall provide the qualifications of any contractor or principal subcontractor.

The Settling Parties shall obtain a certification from any contractor or principal subcontractor that said contractor or principal subcontractor is properly licensed to perform work in the State of Louisiana.

B. EPA and DEQ shall each appoint one Project Coordinator ("PC"). EPA and DEQ will designate one of their Project Coordinators to be the Principal Project Coordinator ("PPC"), who shall be responsible for overseeing implementation of this Consent Decree and stating the coordinated position of EPA and DEQ. EPA and DEQ shall notify the Settling Parties prior to initiation of the remedial action of the identity and address of the PPC.

C. The PPC will observe and monitor the progress of the remedial action. The PPC shall be designated by EPA and Louisiana to be an On-Scene Coordinator as defined by the NCP, with such authority as is vested by the NCP, 40 C.F.R. § 300 et seq. In addition, the PPC shall have the authority to halt work at the Site in the event Site conditions present an imminent and substantial endangerment and to take any necessary removal action to remedy such endangerment.

D. The Project Coordinators do not have the authority to modify in any way the terms of this Decree, including Attachment C or the SOW. However, the PPC can make decisions concerning the meaning of the SOW. Any such decision

shall be noted in the monthly progress reports submitted by the Settling Parties. The absence of any PC from the Site shall not be cause for stoppage of the remedial action. EPA, DEQ and the Settling Parties have the right to change Project Coordinators. Such a change shall be accomplished by notifying the other party in writing at least seven calendar days prior to the change.

E. The PPC may assign other representatives, including other EPA or DEQ employees or contractors to serve as a Site representative for observation of performance of daily operations during remedial activities. The Site representatives have only the authority to be present and observe performance of the remedial action at the Site. EPA and DEQ will notify the Settling Parties' project coordinator of the identity and presence of a designated Site representative at the Site.

F. To the maximum extent feasible, communications between the Settling Parties and EPA and DEQ shall be made between Project Coordinators. The Project Coordinators shall, whenever possible, operate by agreement, and attempt to resolve disputes or questions concerning the remedial action informally.

VIII. REPORTING AND APPROVALS/DISAPPROVALS

A. Monthly Progress Reports

1. The Settling Parties shall provide written progress reports to the EPA and DEQ on a monthly basis during Phase I and Phase II of the remedial action. These progress reports shall describe the actions which have been taken toward achieving compliance with this Consent Decree, including a general description of remedial activities commenced or completed during the reporting period, remedial activities projected to be commenced or completed during the next reporting period, and any problems that have been encountered or are anticipated by the Settling Parties in commencing or completing the scheduled remedial activities. These progress reports are to be submitted to EPA and DEQ by the tenth working day of each month for work done the preceding month and planned for the current month.

2. If a progress report submitted by the Settling Parties is deemed to be deficient, the PPC shall notify the Settling Parties within fifteen (15) days of receipt of such progress report by the EPA and DEQ. The notice shall include an explanation why the report is deficient, including the technical and legal basis therefor.

3. Within fifteen (15) working days of receipt by Settling Parties of a notice of deficiency of a progress report, the Settling Parties shall make the necessary changes and resubmit the progress report to EPA and DEQ or notify EPA and DEQ that they disagree with the notice of deficiency.

4. If the parties cannot resolve disagreement concerning the notice of deficiency, and if EPA and DEQ continue to believe the progress report to be deficient, then EPA and DEQ may seek stipulated penalties, subject to the Dispute Resolution provisions of Section XIX of this Consent Decree.

B. Other Reports, Plans, and Other Items

1. If any plans, reports (other than the progress reports which are covered by Section VIII.A.1,) or other items required to be submitted to EPA and DEQ for approval pursuant to this Consent Decree are disapproved by EPA and DEQ, then the Settling Parties shall have thirty (30) days (or such other time as the parties agree is reasonably necessary to complete the required task) from the receipt of such disapproval to correct any deficiencies and resubmit the item/report for EPA and DEQ approval.

2. Any disapprovals by EPA and DEQ shall include an explanation of why the report, plan, or item is being disapproved, including the technical and legal basis therefor.

3. The Settling Parties must address each of EPA's and DEQ's comments and resubmit to the PPC the previously disapproved report, plan or item with the appropriate changes within the deadline set forth herein.

4. If the parties cannot resolve disagreement concerning the notice of deficiency, and if EPA and DEQ continue to believe the progress report to be deficient, then EPA and DEQ may seek stipulated penalties, subject to the Dispute Resolution provisions of Section XIX of this Consent Decree.

IX. WORKER HEALTH & SAFETY PLAN

The Settling Parties will prepare and submit to the United States and Louisiana in accordance with the schedule contained in the SOW a worker health and safety plan ("WHSP") that satisfies the requirements of the Occupational Safety and Health Guidance for Hazardous Waste Activities and EPA's Standard Operating and Safety Guides. The Settling Parties shall implement the plan after EPA and DEQ approve it.

X. QUALITY ASSURANCE/QUALITY CONTROL

The Settling Parties will prepare and submit to the United States and Louisiana a Quality Assurance Project Plan ("QA/PJP") for remedial design activities and a QA/PJP for remedial action activities which shall be consistent with EPA's Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. The Settling Parties shall implement the plan after EPA and DEQ approve it. The Settling Parties shall utilize the QA/PJP in connection with activities conducted pursuant to this Consent Decree. EPA and DEQ shall utilize the federal government's quality assurance and quality control procedures which are in effect at the time of any remedial activity and shall provide the Settling Parties with a copy of such procedures.

XI. SITE ACCESS

During the effective period of this Decree the Owner shall permit EPA, Louisiana, the Settling Parties and their representatives, including contractors, to have access at all times to the Site and any contiguous property for purposes of performing activities required hereunder and for conducting any activity authorized by CERCLA, RCRA, or LEQA including but not limited to:

A. Monitoring the progress of the remedial action;

B. Verifying any data or information submitted to EPA and DEQ with respect to the remedial action at the Site;

C. Conducting investigations relating to contamination at or near the Site;

D. Inspecting sampling procedures and obtaining samples collected by the Settling Parties at the Site; and

E. Inspecting and copying records, operating logs, contracts, or other documents pertaining to implementation of the Consent Decree that are required to assess the Settling Parties' compliance with the Consent Decree. Where Settling Parties believe that any such records, operating logs, contracts, or other documents are privileged, such documents shall be segregated and withheld from inspection. A list identifying such alleged privileged documents shall be provided to EPA and DEQ within fifteen (15) days after EPA and DEQ undertake an inspection. Should EPA and DEQ contest the Settling Parties' claim of confidentiality, EPA and DEQ may invoke the procedures for Dispute Resolution.

In addition, the Settling Parties will not object to EPA's or DEQ's obtaining access to any analytical labora-

tory which is performing part of the remedial action to allow EPA and DEQ to determine such laboratory's compliance with the approved QA/PJP. Nothing herein limits or otherwise affects any right of entry or sampling which the United States or Louisiana have pursuant to applicable laws, regulations, or permits.

XII. INSURANCE/FINANCIAL RESPONSIBILITY

Anything herein notwithstanding, in no event shall the Settling Parties be relieved of their ultimate responsibility to implement the remedial action under this Consent Decree in a timely fashion by reason of any inability to obtain or failure to maintain in force any insurance policies, or by reason of any dispute between the Settling Parties and any of their insurers pertaining to any claim arising out of the design, construction, implementation, or operation of the remedial action, or arising out of any other activity required under this Consent Decree.

XIII. SUBMISSION OF DOCUMENTS, SAMPLING, AND ANALYSIS

A. The Settling Parties shall submit a quality assurance report to EPA and DEQ, on a quarterly basis, by the 45th calendar day following the end of each quarter after the remedial action is commenced. This report shall contain the information and documents required by the QA/PJP.

B. The Settling Parties shall take such samples as are required by the SOW and this Consent Decree.

C. The Settling Parties shall give the PPC seven (7) days verbal notice of any sampling conducted pursuant to this Consent Decree by them or by anyone acting on their behalf at the Bayou Sorrel Site. (Verbal notice shall be confirmed by written notice to EPA and DEQ.) The Settling Parties shall require by contract and use their best efforts to insure that samples shall be retained and disposed of by their analytical laboratories in accordance with EPA's customary contract laboratory procedures for sample retention. If a laboratory fails to retain samples as required by its contract with the Settling Parties, the parties will discuss whether the laboratory should continue to perform analytical work required by this Consent Decree. At EPA's and DEQ's written request stating the reasons therefor, the Settling Parties shall discontinue use of the laboratory. If the Settling Parties disagree, they shall initiate Dispute Resolution within thirty (30) days. Upon request from the PPC, the sample or a split thereof shall be sent to the PPC or his designee.

D. Representatives of EPA and DEQ shall have the right to take one split of any sample obtained by the Settling Parties or anyone acting on the Settling Parties' behalf at

the Bayou Sorrel Site during the implementation of the remedial action or operation and maintenance phase.

XIV. RETENTION OF RECORDS

A. All the Settling Parties shall preserve and retain one copy of records and documents that are required to be generated by the terms of this Consent Decree or records and documents now in their possession or control that relate to the amount and type of materials sent to the Bayou Sorrel Site by any party for six (6) years after the completion of the remedial action set forth in Section V above.

B. Until completion of the remedial action and termination of this Consent Decree, the Settling Parties shall preserve, and shall instruct all contractors, subcontractors, and agents acting on the Settling Parties' behalf at the Bayou Sorrel Site to preserve all records, documents, and information of whatever kind, nature, or description relating to the performance of the remedial action at the Site. Upon the completion of the remedial action, copies of all such records, documents, and information shall be delivered to the EPA Project Coordinator.

C. This Section XIV shall not apply to documents prepared by or prepared for legal counsel of any settling

party as part of their legal representation of members of the Settling Parties which are in counsel's possession.

D. All data, factual information, and documents required to be submitted by the Settling Parties to EPA and DEQ pursuant to this Consent Decree shall be subject to public inspection unless the Settling Parties assert a claim that such documents are or contain trade secrets or confidential business information or are legally privileged from disclosure. The Settling Parties shall have the burden of demonstrating such confidentiality or privilege exists. The Settling Parties shall not assert a claim of confidentiality or privilege regarding data required to be generated under the terms of this Consent Decree, including any hydrogeological or chemical data, any data submitted in support of a remedial proposal, or any other scientific or engineering tests. All documents pertaining to the Site and the completion of the remedial action in the possession of United States and Louisiana which are releaseable under the Freedom of Information Act, Section 104(e) of CERCLA, or other freedom of information laws or regulations, shall be retained by them for six (6) years following completion of the remedial action set forth in Section V above and shall be available on reasonable notice for inspection and copying by the Settling Parties.

XV. RESPONSE COST REIMBURSEMENT

A. Within thirty (30) days of the final entry of this Consent Decree, the Settling Parties shall pay the total sum of $800,000 to the United States and to the State of Louisiana which shall fully discharge the obligation of the Settling Parties for all response costs incurred by the United States and Louisiana prior to June 15, 1987.

B. The Settling Parties shall reimburse the United States and Louisiana up to the amount of $1.885 million for the necessary costs of overseeing the implementation of this Consent Decree, excluding activities conducted pursuant to Section VI.G. The Settling Parties shall reimburse the United States and Louisiana for the necessary costs of overseeing the implementation of actions conducted pursuant to Section VI.G of this Consent Decree. The United States and Louisiana shall provide the Settling Parties with a statement of costs on the 1st day of February of each year following the entry of this Consent Decree, until this Decree terminates, covering oversight costs incurred in the previous fiscal year. The statement of costs shall provide the Settling Parties with an explanation of the amount, date, description of activity, purpose, entity or person to whom paid and manner of calculation of all oversight costs. The United States and Louisiana shall make available upon request the underlying cost documentation, including any auditors'

reports, and shall designate persons with knowledge of the incurrence of costs and the audit, to answer reasonable questions of the Settling Parties concerning them. Within thirty (30) days of their receipt of the information requested from the United States and Louisiana, the Settling Parties shall, subject to their right to invoke the provisions of Section XIX, reimburse the United States and Louisiana for oversight costs not to exceed the amounts set forth above. Payment of such oversight costs shall fully discharge the obligation of the Settling Parties to pay response costs for oversight of this Consent Decree conducted by the United States and Louisiana. In the event the United States and Louisiana incur oversight costs with respect to activities conducted pursuant to Section VI.G, they will provide the Settling Parties with an accounting for such costs in the manner and at the time set forth above with respect to oversight costs.

XVI. COVENANT NOT TO SUE

A. Except as expressly provided herein, the United States and the State of Louisiana hereby covenant not to sue or take any administrative action against the Settling Parties for any and all civil liability, including future liability, to the United States and Louisiana for causes of action arising under CERCLA, RCRA § 7003 and the Laws of the State of Louisiana for claims arising from or

relating to the Site. With respect to future liability, this covenant not to sue shall take effect upon certification by EPA and DEQ that the remedial action, except for operation and maintenance, has been completed in accordance with the SOW.

B. The Settling Parties hereby covenant not to sue the United States and Louisiana for any claim for the cost of the Settling Parties' performing the remedial action governed by this Consent Decree, including any direct or indirect claims for reimbursement from the Hazardous Substance Response Trust Fund, 42 U.S.C. §9611. The Settling Parties reserve their rights to assert claims arising out of or in connection with the negligent acts or omissions or willful misconduct of the United States or Louisiana, or their agents, employees, contractors or representatives. Nothing in this Consent Decree shall be deemed to constitute pre-authorization of a CERCLA claim within the meaning of Section III of CERCLA and 40 C.F.R. §300.25(d). Nothing contained herein shall constitute any waiver, release or covenant not to sue by the Settling Parties of any agency, department, contractor or instrumentality of the United States for contribution under any provision of state or federal law including any statute, common law, §107, §113 of CERCLA and RCRA for conditions at the Site.

C. The provisions of Paragraph A of this Section shall not apply to the following:

1. Claims based on a failure by the Settling Parties to comply with this Consent Decree;

2. Claims based on the Settling Parties' liability arising from the past, present, or future disposal of waste materials off of the Bayou Sorrel Site;

3. Claims for damages to natural resources as defined in CERCLA;

4. Criminal liability; and

5. Any claim for damages to federal or state property.

D. The parties have determined on the basis of currently available information that the Remedial Action, as reflected in the SOW, and provided under this Consent Decree is consistent with the ROD, § 121 of CERCLA and the NCP and is adequate to abate the release or threat of release of hazardous substances from the Site to the surrounding environment; and, further, the parties do not believe at this time that additional action beyond that described herein in the ROD and the SOW and Attachments to this Consent Decree is

necessary to protect public health or the environment at the Site. Therefore, except as provided in Section VII.C, during Phase I, Phase II and any activities conducted pursuant to Section VI.G (including dispute resolution conducted pursuant to Section XIX), and so long as the Settling Parties implement the SOW, the United States and Louisiana agree not to undertake or seek to require the Settling Parties to undertake additional response measures at the Bayou Sorrel Site other than those required in the SOW or pursuant to Section VI.G. EPA or DEQ may conduct oversight of the remedial action necessary to assess the compliance of the Settling Parties with the terms of the Consent Decree and the SOW.

However, presently unknown conditions at the Site or a review of the remedy pursuant to § 121(c) of CERCLA may demonstrate that further response action is appropriate. Therefore, the United States and Louisiana reserve the right to institute proceedings in this action seeking to compel the Settling Parties to perform additional response work at the Site or seek reimbursement for performance of such additional response work, if:

1. Conditions at the Site previously unknown to the United States and Louisiana except as covered by Section VI.G, as to which the President is authorized to take response action under 42 U.S.C. § 9604(a)(1), are discovered after the lodging of this Consent Decree or, for proceedings

instituted after EPA and DEQ certify that the Remedial Action has been completed, following the certification; or

2. The President determines pursuant to a review of the remedy under § 121(c) of CERCLA that the remedial action hereunder is no longer protective of human health and the environment.

E. The Settling Parties reserve all rights, defenses, claims, causes of action or counterclaims which they may have at law or equity to defend against, oppose or contest any claim brought by the United States or Louisiana pursuant to Section XVI.D of this Consent Decree and to make any claim it may have, including the right to make a claim against the Hazardous Response Superfund, other than for response costs incurred by the Settling Parties prior to the entry of this Consent Decree or the cost of performing the remedial action hereunder.

XVII. STIPULATED PENALTIES

A. Subject to the force majeure and dispute resolution provisions in Sections XVIII and XIX of this Consent Decree, the Settling Parties shall pay stipulated penalties as set forth below:

(1) For failure to submit monthly progress reports, other reports required by Section IX of this Consent Decree, or reports required by Section XIV, in a timely fashion, the Settling Parties shall pay stipulated penalties in the following amounts for each day during which the violation continues:

Period of Failure to Comply	Penalty Per Violation Per Day
1st through 14th day	$500
15th through 44th day	$1,000
45th day and beyond	$2,000

(2) For failure to meet the deadlines established in figure 3-3 of the SOW for items 3, 6, 7, 8, 9 and 10, the Settling Parties shall pay stipulated penalties in the following amounts for each day of violation:

Period of Failure to Comply	Penalty Per Violation Per Day
1st through 14th day	$2,000
15th through 44th day	$4,000
45th day and beyond	$8,000

(3) For failure to undertake the remedial action in accordance with the SOW (except with respect to timely completion which shall be governed by

Section A.(2) above), the Settling Parties shall pay stipulated penalties in the following amounts for each day during which the violation continues. Provided, however, that stipulated penalties shall not begin to accrue under this sub-paragraph until EPA and DEQ have notified the Settling Parties of such failure in writing and provided the Settling Parties a reasonable opportunity to cure any such failure:

Period of Failure to Comply	Penalty Per Violation Per Day
1st through 14th day	$2,000
15th through 44th day	$5,000
45th day and beyond	$10,000

B. Stipulated penalties under this paragraph shall be paid by certified or cashier's check and shall be paid by the 15th day of the month following the month in which the violation occurs, or, where applicable, notice of the violation is given or upon final resolution pursuant to Section XIX. The United States and Louisiana shall notify the Settling Parties in writing of violations of this Consent Decree. Only with respect to penalties which may be assessed under paragraph A.(3) above, no stipulated penalties shall be due for any period of failure to comply during which the United

States and Louisiana did not comply with the notice provisions of paragraph A.(3) above. During the pendency of and pending the resolution of any dispute resolution pursuant to Section XIX of this Consent Decree, the Settling Parties shall not be required to pay any stipulated penalties. If the Settling Parties are successful in any dispute resolution pursuant to Section XIX of this Consent Decree, they shall have no liability to pay stipulated penalties or other sanctions with regard to the matter submitted for dispute resolution. In the event the Settling Parties are unsuccessful in dispute resolution, the Settling Parties shall be liable for stipulated penalties as set forth in Section XVII.A (1-3), as applicable. Stipulated penalties shall begin to accrue from the date of violation or, where applicable, the failure to cure after notice, until the violation is corrected. Payment shall be made within thirty (30) days of any ruling by the Court unless the Court finds that the Settling Parties' position was substantially justified, in which case, the Court may reduce the stipulated penalties as appropriate, but in no event shall the reduction be more than fifty percent (50%). Payment shall be made in the following manner:

1. Sixty percent (60%) of the stipulated penalties shall be paid to the United States to the Hazardous Substance Response Trust Fund. A copy of the check and the letter forwarding the check, including a brief description of the non-

compliance, shall be submitted to the United States in accordance with Section XX, herein; and

2. Forty percent (40%) of the stipulated penalties shall be paid to the Louisiana Department of Environmental Quality and designated for the Hazardous Waste Site Cleanup Fund pursuant to LSA R.S. 30:1149. The check and the letter shall be mailed to the State of Louisiana in accordance with Section XX, herein.

C. In addition to the stipulated penalties set forth above, the United States and Louisiana specifically reserve the right to seek other remedies or sanctions available to the United States and Louisiana by reason of the Settling Parties' failure to comply with the requirements of this Consent Decree, including sanctions and penalties that the United States and Louisiana may seek under § 122(1) of CERCLA. Provided, however, that the penalties paid hereunder shall be credited against any monetary sanctions or penalties which the Settling Parties may be required to pay in the event the United States and Louisiana seek additional relief against the Settling Parties. The Settling Parties reserve all rights they have to defend against, oppose and contest any such claim by the United States or Louisiana.

D. The parties agree that a single act or omission shall not be the basis for more than one penalty.

XVIII. FORCE MAJEURE

A. Any failure by the Settling Parties to complete the Work in accordance with the approved SOW or to submit reports or documents required by this Consent Decree which results from circumstances beyond the reasonable control of the Settling Parties shall not be deemed to be a violation of Settling Parties' obligations under this Consent Decree. To the extent a delay is caused by circumstances beyond the reasonable control of the Settling Parties or is caused by the United States or Louisiana, the time period for performance hereunder shall be suspended for a period of time at least equal to the duration of the delay or an amount which is reasonably calculated to allow the Settling Parties to compensate for the occurrence which was beyond their reasonable control. When the force majeure condition ceases to exist, the Settling Parties shall resume the Work.

B. The Settling Parties shall notify EPA and DEQ of any delays which occur in the performance of the remedial action required under this Consent Decree. Notification shall be made within fifteen (15) days after Settling Parties learn a delay in performance of the work will occur. Notification shall be in writing and shall describe the nature of the delay; the reasons therefor; the expected duration of the delay; and the actions which will be taken to mitigate future delay. The Settling Parties shall adopt reasonable measures to avoid

or minimize any such delay. Failure to provide such notification as provided herein shall constitute a waiver by Settling Parties of their right to invoke the provisions of this section as a basis for excusing delay of their performance under this Consent Order.

C. Force Majeure shall not include increased costs or expenses of the remedial action or any unwillingness or inability to pay of any one or more of the Settling Parties. The Settling Parties agree and commit to complete all the remedial actions and activities provided for in this Consent Decree.

XIX. DISPUTE RESOLUTION

In the event that the parties cannot resolve any dispute arising under this Decree, from the completion of the Work, or from the implementation of this Decree, then the interpretation advanced by the United States and Louisiana shall be considered binding unless the Settling Parties invoke the Dispute Resolution provisions of this Section.

Any dispute that arises with respect to the meaning or application of this Consent Decree or the SOW shall in the first instance be the subject of informal negotiations between the parties. Such period of informal negotiations

shall not extend beyond thirty (30) days, unless the parties agree otherwise in writing.

Within thirty (30) days of written notification to the Settling Parties by the United States and Louisiana of the termination of informal negotiations, should the Settling Parties choose not to follow the United States' and Louisiana's position, the Settling Parties shall file with the Court a petition which shall describe the nature of the dispute and include a proposal for its resolution. The filing of a petition asking the Court to resolve a dispute shall not of itself postpone the deadlines for the Settling Parties to meet their obligations under this Decree or stay the accrual of stipulated penalties with respect to the disputed issue. However, the obligation to pay stipulated penalties shall be stayed pending resolution of the dispute. The United States and Louisiana shall have thirty (30) days to respond to the petition.

In any dispute resolution proceeding involving matters covered by Section 113(j) of CERCLA, the Court shall apply the standards and provisions of section 113(j) and (k) of CERCLA. Unless otherwise specifically set forth herein, the failure to provide expressly for dispute resolution in any section of this Consent Decree is not intended and shall not bar the Settling Parties from invoking this Section as to any disputed issue arising under this Consent Decree.

XX. FORM OF NOTICE

All notices required to be given pursuant to this Consent Decree shall be in writing unless otherwise expressly authorized and shall be deemed to have been made upon receipt of a certified letter delivered to the persons specified in this subparagraph. Documents, including reports, approvals, and other correspondence, to be submitted pursuant to this Consent Decree shall be sent by certified mail to the following addresses or to such other addresses as the Settling Parties, EPA and the DEQ hereafter may designate in writing:

As to the United States

Office of Regional Counsel
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

and

Chief, Superfund Enforcement Branch
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

and a copy to

The EPA Project Coordinator - Bayou Sorrel Site
Superfund Branch
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

And to EPA Consultants as directed.

As to Louisiana

Louisiana Department of Justice
Environmental Enforcement Section
7434 Perkins Road, Suite C
Baton Rouge, LA 70808

and

Louisiana Department of Environmental Quality
Inactive & Abandoned Sites Division
P.O. Box 44307
Baton Rouge, LA 70804

As to the Settling Parties.

Leonard L. Kilgore, III, Esq.
c/o Bayou Sorrel Steering Committee
P.O. Box 3513
Baton Rouge, LA 70821

XXI. MODIFICATION

Except as provided for herein, there shall be no modification of this Consent Decree without written approval of all parties to this Consent Decree.

XXII. ADMISSIBILITY OF DATA

No party shall object to the admissibility of analytical data that it gathers and generates on the grounds of its own failure to maintain chain of custody or hearsay.

If data was gathered and generated by the Settling Parties and the Settling Parties seek to introduce it into evidence, the United States and Louisiana will waive any evidentiary objection to admissibility of such evidence based on failure to maintain proper chain of custody or hearsay, if the Settling Parties have complied with QA/PJP. The Settling Parties may make this demonstration through one summary witness per laboratory.

If the data was gathered and generated by United States and Louisiana, and United States and Louisiana seek to introduce it into evidence, the Settling Parties will waive any evidentiary objection to admissibility of such evidence based on failure to maintain proper chain of custody or hearsay, if United States or Louisiana have complied with QA/QC procedures utilized by the United States pursuant to Section XI above. The United States and Louisiana may make this demonstration through one summary witness per laboratory.

XXIII. EFFECTIVE DATE

This Consent Decree is effective upon the date of its entry by the Court.

XXIV. RETENTION OF CLAIMS

A. It is not a purpose of this Consent Decree nor the intention of the parties to release any other persons or entities not parties to this Consent Decree, including the United States Department of Energy from any claims or liabilities which may exist, the right to pursue which is expressly reserved.

B. Nothing herein is intended by any of the parties to create any private causes of action in favor of any person not a signatory to this Consent Decree or to release any party not a signatory to this Consent Decree from any liability, duty, responsibility or otherwise which they might have at law or equity, against any party not a signatory hereto.

XXV. INDEMNIFICATION

The Settling Parties agree to indemnify, save and hold harmless the United States and Louisiana from any and all claims or causes of action arising from negligent acts or omissions or willful misconduct of the Settling Parties in carrying out activities for which the Settling Parties are responsible pursuant to this Consent Decree.

XXVI. LIABILITY

The United States and Louisiana shall not be liable for any injuries or damages to persons or property resulting from any acts or omissions of the Settling Parties, their officers, employees, agents, receivers, trustees, successors, assigns, contractors, subcontractors or any other person acting on their behalf in carrying out any activities pursuant to the terms of this Consent Decree. The Settling Parties shall not be liable for and do not assume liability for any injuries or damages to persons or property resulting from acts or omissions of the United States or Louisiana or any person acting by, through or under them or on their behalf in carrying out any activity under this Consent Decree.

XXVII. OTHER CLAIMS

Nothing in this Consent Decree shall constitute or be construed as a release from any claim, cause of action, or demand in law or equity against any person, firm, partnership, or corporation not a signatory to this Consent Decree for any liability it may have arising out of or relating in any way to the generation, storage, treatment, handling, transportation, release, or disposal of any hazardous substances, hazardous wastes, pollutants, or contaminants found at, taken to, or taken from the Bayou Sorrel Site.

XXVIII. CONTINUING JURISDICTION

The parties agree to submit to this Court all disputes pertaining to this Consent Decree and the Court specifically retains jurisdiction over both the subject matter of and the parties to this action for the duration of this Consent Decree for the purposes of issuing such further orders or directions as may be necessary or appropriate to construe, implement, modify, enforce, terminate, or reinstate the terms of this Consent Decree, or for further relief which the interests of justice may require.

XXIX. TERMINATION AND SATISFACTION

We hereby consent to the entry of this Consent Decree subject to the provisions of 28 CFR §§ 50.7 and § 122(1) of CERCLA.

The Consent Decree shall terminate upon notification to the Court by the United States and Louisiana that the terms and conditions of this Consent Decree have been satisfactorily fullfilled. If the Settling Parties request in writing that the United States and Louisiana notify the Court

that the Settling Parties have complied with the terms and conditions of this Consent Decree, and the United States and Louisiana do not provide such notification to the Court within thirty (30) days, then the Settling Parties shall have the right to invoke dispute resolution.

FOR THE UNITED STATES OF AMERICA

ROBERT E. LAYTON, Jr.
Regional Administrator
U.S. Environmental Protection Agency
Region VI
Dallas, Texas 75202

Dated: October 7, 1987

JAMES O. NEET, JR.
Acting Regional Counsel
U.S. Environmental Protection Agency
Region VI
Dallas, Texas 75202

Dated: September 30, 1987

PAMELA PHILLIPS
Senior Assistant Regional Counsel
U.S. Environmental Protection Agency
Region VI
Dallas, Texas 75202

Dated: September 28, 1987

for THOMAS L. ADAMS, JR.
Assistant Administrator for
Enforcement & Compliance Monitoring
U. S. Environmental Protection Agency
Washington, D.C. 20460

Dated: November 13, 1987

ROGER A. MARZULLA
Acting Assistant Attorney General
Land and Natural Resources Division
U.S. Department of Justice
Washington, D.C. 20530

Dated: December 7, 1987

P. RAYMOND LAMONICA
United States Attorney
Middle District of Louisiana
Federal Building
Baton Rouge, LA 70801

Dated: _____

STATE OF LOUISIANA,
Plaintiff.

WILLIAM J. GUSTE, JR.
Attorney General
State of Louisiana
Department of Justice

MARTHA A. MADDEN, Secretary
Louisiana Department of
Environmental Quality
Post Office Box 44066
Baton Rouge, Louisiana 70804
(504) 342-1265

GARY L. KEYSER, Chief
Lands and Natural Resources
Division
Assistant Attorney General
La. Department of Justice
7434 Perkins Road, Suite C
Baton Rouge, Louisiana 70808
(504) 765-2416

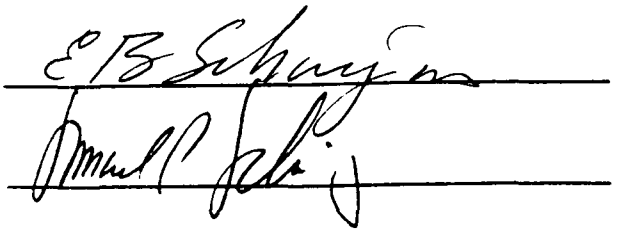
ROLAND T. HUSON
General Counsel
Louisiana Department of
Environmental Quality
Post Office Box 44066
Baton Rouge, Louisiana 70804
(504) 342-1240

JOHN B. SHEPPARD, JR., Chief
Environmental Enforcement
Section
Assistant Attorney General
La. Department of Justice
7434 Perkins Road, Suite C
Baton Rouge, Louisiana 70808
(504) 765-2416

WILLIAM B. DEVILLE
Administrator
Inactive and Abandoned Sites
Division
Louisiana Department of
Environmental Quality
Post Office Box 44307
Baton Rouge, Louisiana 70804
(504) 342-8925

WARREN E. BYRD, II
Assistant Attorney General
Environmental Enforcement
Section
La. Department of Justice
7434 Perkins Road, Suite C
Baton Rouge, Louisiana 70808
(504) 765-2416

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of the parties listed on Exhibit A, who are the owners of the Bayou Sorrel site. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of all of the owners of the Bayou Sorrel site.



Dated: September 15, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of ALLIED CORPORATION, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of ALLIED CORPORATION.

YES
FILED
ALLIED
LAW DEPT

ALLIED CORPORATION*
(Company)

By: Paul H. Arbesman

Dated: September 9, 1987.

* formerly Allied Chemical Company

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of AMERICAN CYANAMID COMPANY, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of AMERICAN CYANAMID COMPANY.

AMERICAN CYANAMID COMPANY
(Company)

By: _____ 9/10/07

Dated: _____, 1987.

The undersigned, ARCO Chemical Company, on its behalf and on behalf of Atlantic Richfield Company, and as successor to Oxirane Chemical Company and Oxirane Chemical Company (Channelview), and each of their stockholders, partners, predecessors, successors and assigns (the "Settling Parties"), consents to the entry of this Consent Decree concerning the Bayou Sorrel site. The undersigned individual represents that he is authorized to sign this Consent Decree on behalf of the Settling Parties.

By: _____

MORRIS GELB, VICE PRESIDENT
ARCO CHEMICAL COMPANY

Dated: September 4, 1987

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of BASF Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of BASF Corporation.

BASF Corporation
(Company)

By: Keith Fry
Keith Fry

Dated: August 26, 1987.

BASF Corporation is the successor of BASF Wyandotte Corporation.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Betz Laboratories, Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Betz Laboratories, Inc..

BETZ LABORATORIES, INC.
(Company)

By: William C Bruff

Dated: September 10, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of BORDEN, INC., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of BORDEN, INC..

BORDEN, INC.
(Company)

By: John Bellecci 9/1/87

Dated: Sept 1, 1987.

mdo 9/1/87

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Cedar Chemical Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Cedar Chemical Corporation.

CEDAR CHEMICAL CORPORATION
(Company)

By: John C Bumpers
V.P. - Fin/Admin

Dated: August 28, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Chemical Waste Management, Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Chemical Waste Management, Inc.

Chemical Waste Management, Inc.
(Company)

By: _____

Dated: September 4, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Chevron U.S.A. Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Chevron U.S.A. Inc..

Chevron U.S.A. Inc, acting by and through Warren Petroleum Company, a (Company) division thereo

ATTEST:

Assistant Secretary

By: _____

Title: Vice President

Dated: Sept. 2, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of "Chevron", which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Chevron Chemical Company.

Chevron Chemical Company
(Company)

By: _____
Manager, Environment and
Health Protection

Dated: September 3, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of CIBA-GEIGY Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of CIBA-GEIGY Corporation.

CIBA-GEIGY Corporation
(Company)

By: R. Bernegger
Dr. Rolf Bernegger

Dated: 8.26.87, 1987. TLG

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Cities Service Oil and Gas Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Cities Service Oil and Gas Corporation.

Cities Service Oil and Gas Corporation
(Company)

By: _____
Herman A. Fritschen

Dated: August 27, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Conoco Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Conoco Inc..

Conoco Inc.
(Company)

By: T. E. Davis

T. E. Davis
Vice President
Natural Gas & Gas Products Dept.

Dated: Sept. 9, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Cos-Mar Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Cos-Mar Company.

Cos-Mar Company
(Company)

By: R J Comeaux

Dated: September 11 , 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Degussa Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Degussa Corporation.

Degussa Corporation
(Company)

By: _____
Richard M. Ornitz

Dated: 8/27, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of The Dow Chemical Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of The Dow Chemical Company.

The Dow Chemical Company
(Company)

By: RW Gallant RSC

Dated: August 31, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Earth Industrial Waste Management, Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Earth Industrial Waste Management, Inc..

Earth Industial Waste Management, Inc.
(Company)

By: _____

Dated: September 8, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Ethyl Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Ethyl Corporation.

Ethyl Corporation
(Company)

By: Donald E. Park
Director of Environmental Affairs

Dated: September 3, 1987.

Please return to
David C. Bach, Esq.
ETHYL CORPORATION
451 Florida St., Rm. 927
Baton Rouge, LA 70801

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Exxon Chemical Americas, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Exxon Chemical Americas.

a division of Exxon Chemical Company,
a division of Exxon Corporation

Exxon Chemical Americas
(Company)

By: K N Robertson

Dated: August 21, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Freeport-McMoran Resource Partners, Limited Partnership, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Freeport-McMoran Resource Partners, Limited Partnership.

Freeport-McMoran Resource Partners,
Limited Partnership
(Company)

By: Roger T. Baker

Dated: September 9, , 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of General Electric Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of General Electric Company.

General Electric Company
(Company)

By: Robert W. Hunt

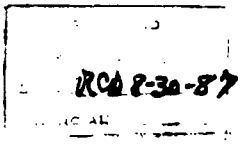
Dated: September 2, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of HALLIBURTON SERVICES, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of HALLIBURTON SERVICES.

HALLIBURTON SERVICES
(Company)

By: _____
A.A. Baker, President

Dated: August 31, 1987.



The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Helena Chemical Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Helena Chemical Company.

Helena Chemical Company
(Company)

By: [signature]
Vice President of Operations
and Administration

Dated: September 1, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Hercules Incorporated, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Hercules Incorporated.

David S. Hollingsworth (Company)

By: David S. Hollingsworth
Chairman and Chief Executive Officer

Dated: August 26, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of ICI Americas Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of ICI Americas Inc.

ICI AMERICAS INC.
(Company)

By: J. Kent Riegel
mtl.

Dated: September 4, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Ingalls Shipbuilding, Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Ingalls Shipbuilding, Inc.

INGALLS SHIPBUILDING, INC.
(Company)

By: George W. Howell
George W. Howell
Vice President and General Counsel

Dated: September 9, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Kaiser Aluminum & Chemical Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Kaiser Aluminum & Chemical Corporation.

Kaiser Aluminum & Chemical Corporation
(Company)

By: J E Sparkman
J. E. Sparkman
Vice President

Dated: August 31, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Marathon Petroleum Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Marathon Petroleum Company.

Marathon Petroleum Company
(Company)

By: R K McCord
R. K. McCord

Dated: September 3, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Martin Marietta Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Martin Marietta Corporation.

MARTIN MARIETTA CORPORATION
(Company)

By: _____
C. E. Carnahan, Vice President
Environmental Management Task Force

Dated: September 2, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Melamine Chemicals, Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Melamine Chemicals, Inc..

Melamine Chemicals, Inc.
(Company)

By: Roger E. Thomas

Dated: 9/8, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Mobil Oil Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Mobil Oil Corporation.

Mobil Oil Corporation
(Company)

By: _____
M. J. Hage
Vice President - Manufacturing
Marketing and Refining-
U.S.

Dated: _____, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Mobil Oil Exploration & Producing Southeast Inc., a wholly-owned subsidiary corporation of Mobil Oil Corporation, which is one of the settling parties. The Undersigned represents that he is authorized to sign this Consent Decree on behalf of Mobil Oil Exploration & Producing Southeast Inc.

Mobil Oil Exploration & Producing Southeast Inc.
(Company)

Dated: 8-28-87

By: _____
J. T. Sneed, Producing Manager,
New Orleans Division of Mobil
Exploration & Producing U.S. Inc.
as agent for Mobil Oil Exploration &
Producing Southeast Inc.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Monsanto Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Monsanto Company.

Monsanto Company
(Company)

By: [signature]

Robert L. Harness
Monsanto Agricultural Company
Vice President
Environmental and Public Affairs

Dated: Sept 4, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Nalco Chemical Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Nalco Chemical Company.

Nalco Chemical Company
(Company)

By: _____

Dated: August 28, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of National Marine Service Incorporated, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of National Marine Service Incorporated.

National Marine Service Incorporated
(Company)

By: _____

Vice President, NICOR National Inc.,
Attorney-in-fact for National Marine
Service Incorporated

Dated: August 27, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of New Orleans Public Service Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of New Orleans Public Service Inc..

New Orleans Public Service Inc.
(Company)

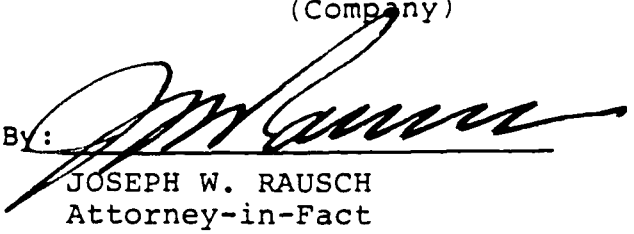
By: _____

John J. Cordaro
Sr. Vice President - External Affairs

Dated: August 28, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of NORDIX, INCORPORATED, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of NORDIX, INCORPORATED.

NORDIX, INCORPORATED
(Company)

By: 
JOSEPH W. RAUSCH
Attorney-in-Fact

Dated: August 22, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of North American Philips Corporation which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of North American Philips Corporation.

North American Philips Corporation
(Company)

By: _____
James S. Cole
Vice President

Dated: September 3, , 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Occidental Chemical Corporation (formerly Hooker Chemicals & Plastics Corp.), which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Occidental Chemical Corporation (formerly Hooker Chemicals & Plastics Corp.).

Occidental Chemical Corporation (formerly Hooker Chemicals & Plastics Corp.)
(Company)

By: M. J. Rudick

M. J. Rudick
Vice President General Counsel

Dated: August 28, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Occidental Electrochemicals Corporation, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Occidental Electrochemicals Corporation.

Occidental Electrochemicals Corporation
(formerly Diamond Shamrock Chemicals Company)
(Company)

By: M. J. Rudick

M. J. Rudick
Vice President General Counsel

Dated: August 28, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Ohmstede of La., Inc., who are the owners of the Bayou Sorrel site. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of all of the owners of the Bayou Sorrel site.

OHMSTEDE OF LA., INC.

BY: _____
EUGENE R. GROVES

Dated: September 8, 1987.

The undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrell site on behalf of Peabody International Corporation ("PIC") for the benefit of PIC/Peabody VIP Inc./VIP International Inc./Southern Vacuum Industrial Pollution Corp./Vacuum Industrial Pollution Corp. and their predecessors and successors in interest, which collectively are one of the Settling Parties.

PEABODY INTERNATIONAL CORPORATION

By: _____
William D. Sivitz

DATED: September 1, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of PLACID REFINING COMPANY, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of PLACID REFINING COMPANY.

PLACID REFINING COMPANY
(Company)

By: [signature] MED

Dated: Sept 14, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Reagent Chemical & Research, Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Reagent Chemical & Research, Inc..

Reagent Chemical & Research, Inc.
(Company)

By: _____

Dated: August 27, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Rollins Environmental Services (LA), Inc., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Rollins Environmental Services (LA) Inc.

Rollins Environmental Services (LA) Inc
(Company)

By: J. Carlisle Peet

Dated: 9-3, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Shell Oil Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Shell Oil Company.

Shell Oil Company
(Company)

By: T. R. Williams
Manager Environmental Conservation

Dated: September 9, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Stauffer Chemical Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Stauffer Chemical Company.

STAUFFER CHEMICAL COMPANY
(Company)

By: Ethan C Galloway
Ethan C. Galloway
Executive Vice President, Technical

Dated: September 10, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Tenneco Oil Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Tenneco Oil Company.

Tenneco Oil Company
(Company)

By: C. M. Rampacek

C. M. Rampacek
Senior Vice President

Dated: September 1, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of TEXACO INC., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of TEXACO INC..

TEXACO INC.
(Company)

By: R. Keith Lee

Dated: September 8, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of TRIAD CHEMICAL, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of TRIAD CHEMICAL.

Triad Chemical
(Company)

By: B.K Shackelford

Dated: 9-2, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of UNIROYAL CHEMICAL COMPANY, INC., which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of UNIROYAL CHEMICAL COMPANY, INC. .

UNIROYAL CHEMICAL COMPANY, INC.
(Company)
As Successor to the Chemical Business of Uniroyal, Inc.

By: _____
PRESIDENT

Dated: 5/27, 1987.

The undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of the University of Southwestern Louisiana, which is one of the Settling Parties. The undersigned represents that he/she is authorized to sign this Consent Decree on behalf of the University of Southwestern Louisiana.

UNIVERSITY OF SOUTHWESTERN LOUISIANA

BY: _____

Dated: 1/19/88

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of VELSICOL CHEMICAL CORPORATION, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of VELSICOL CHEMICAL CORPORATION.

VELSICOL CHEMICAL CORPORATION
(Company)

By: C.C. Hanson

Dated: 9/8, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Vinings Chemical Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Vinings Chemical Company.

Vinings Chemical Company
(Company)

By: J. Robert Carpenter
J. Robert Carpenter
President

Dated: September 2, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Vulcan Materials Company, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of Vulcan Materials Company.

VULCAN MATERIALS COMPANY
(Company)

By: _____
President, Chemicals Division,
Vulcan Materials Company

Dated: August 31, 1987.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of Weatherford U. S., Inc.*, which is one of the Settling Parties. The Undersigned represents that ~~he~~/she is authorized to sign this Consent Decree on behalf of Weatherford U. S., Inc.*.

WEATHERFORD U. S., INC*
(Company)

By: Suzanne Thomas
Vice President & Secretary

Dated: August 25, 1987.

*corporate successor to Weatherford/Lamb U. S., Inc.

The Undersigned consents to the entry of this Consent Decree concerning the Bayou Sorrel site on behalf of ZAPATA HAYNIE CORPORATION, which is one of the Settling Parties. The Undersigned represents that he/she is authorized to sign this Consent Decree on behalf of ZAPATA HAYNIE CORPORATION.

ZAPATA HAYNIE CORPORATION
(Company)

By: D. W. CASSERLEIGH
COUNSEL

Dated: Sept. 3, 1987.

ATTACHMENT A: SETTLING PARTIES -- OWNERS OF THE SITE

EXHIBIT A--OWNERS

I. Owners of the Bayou Sorrel Site in Iberville Parish, Louisiana at the time of operation of a waste disposal facility by Clean Land, Air and Water Corporation and/or Environmental Purification Advancement Corporation during the approximate period of 1976 through 1978:

Katherine Schwing Bickham
Joseph Delma Cointment, III
Sarah Jane Cointment LeBlanc
Althea Schwing Cointment
Virginia Campbell Hortenstine Becker
Richard Campbell Becker Trust
Haidee Becker Broessler Trust
Ann Brandon Hortenstine Santen
Jay Hortenstine McDowell
Mary Howard Nadler
Joan Schwing Parkerson
E. B. Schwing, III
Sarah Jane Schwing Ford
Sue Slack Moxley Schwing
Lilla Bryant Schwing Knapp
Walter Edward Schwing
Lilla Anne Schwing Blackburn
Charles Edward Schwing
Sue S. Schwing (Mrs. E. B. Schwing, Jr.)
S. P. Schwing, III
Carolyn Schwing Howard

EXHIBIT A--OWNERS (Cont'd)

II. Present owners of the Bayou Sorrel Site in Iberville Parish, Louisiana who did not have any ownership interest in the Site at the time of operation of a waste disposal facility by Clean Land, Air and Water Corporation and/or Environmental Purification Advancement Corporation during the approximate period of 1976 through 1978, and who are signing the Consent Decree through their designated trustees, agents or attorneys in fact to assure access and implementation of the Consent Decree, and any future amendments thereto:

Carolyn Howard Anderson
Samuel P. Schwing IV, Trust
Elizabeth F. Schwing Trust
John Blakemore Schwing Trust
Scott P. Howard
Peter S. Howard
The University of the South
Episcopal Church of the Holy Communion
St. James Episcopal Church
St. Luke's Episcopal Church
L.S.U. Foundation
Edward Beynroth Schwing, IV
Renee Schwing Price
Leo Edward Bickham
Mark Andrew Bickham
Katherine Bickham Bear
Jennifer Ford Trust
Mary Ford Ryan Trust
Richard Haughton Tannehill, Jr.
Sue S. Tannehill
Mary Inez Tannehill
Ann Schwing
Episcopal Radio T-V Foundation, Inc.

ATTACHMENT B: OTHER SETTLING PARTIES

ATTACHMENT B - (OTHER SETTLING PARTIES)

ALLIED CORPORATION

AMERICAN CYANAMID COMPANY

ARCO CHEMICAL COMPANY

BASF CORPORATION

BETZ LABORATORIES, INC.

BORDEN, INC.

CEDAR CHEMICAL CORPORATION

CHEMICAL WASTE MANAGEMENT, INC.

CHEVRON U.S.A. INC.

CHEVRON CHEMICAL COMPANY

CIBA-GEIGY CORPORATION

CITIES SERVICE OIL & GAS CORPORATION

CONOCO INC.

COS-MAR COMPANY

DEGUSSA CORPORATION

THE DOW CHEMICAL COMPANY

EARTH INDUSTRIAL WASTE MANAGEMENT, INC.

ETHYL CORPORATION

EXXON CHEMICAL AMERICAS

FREEPORT-MCMORAN RESOURCE PARTNERS
LIMITED PARTNERSHIP

GENERAL ELECTRIC COMPANY

HALLIBURTON SERVICES

HELENA CHEMICAL COMPANY

HERCULES INCORPORATED

ICI AMERICAS INC.

INGALLS SHIPBUILDING, INC.

KAISER ALUMINUM & CHEMICAL CORPORATION

MARATHON PETROLEUM COMPANY

MARTIN MARIETTA CORPORATION

MELAMINE CHEMICALS, INC.

MOBIL OIL CORPORATION

MOBIL OIL EXPLORATION & PRODUCING
SOUTHEAST INC.

MONSANTO COMPANY

NALCO CHEMICAL COMPANY

NATIONAL MARINE SERVICE INCORPORATED

NEW ORLEANS PUBLIC SERVICE, INC.

NORDIX, INCORPORATED

NORTH AMERICAN PHILIPS CORPORATION

OCCIDENTAL CHEMICAL CORPORATION

OCCIDENTAL ELECTROCHEMICALS CORPORATION

OHMSTEDE OF LA., INC.

PEABODY INTERNATIONAL CORPORATION

PLACID REFINING COMPANY

REAGENT CHEMICAL & RESEARCH, INC.

ROLLINS ENVIRONMENTAL SERVICES (LA), INC.

SHELL OIL COMPANY

STAUFFER CHEMICAL COMPANY

TENNECO OIL COMPANY

TEXACO INC.

TRIAD CHEMICAL

UNIROYAL CHEMICAL COMPANY, INC.

UNIVERSITY OF SOUTHWESTERN LOUISIANA

VELSICOL CHEMICAL CORPORATION

VININGS CHEMICAL COMPANY

VULCAN MATERIALS COMPANY

WEATHERFORD U.S., INC.

ZAPATA HAYNIE CORPORATION

ATTACHMENT C: RECORD OF DECISION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
1201 ELM STREET
DALLAS, TEXAS 75270

RECORD OF DECISION

Site

Bayou Sorrel Site located in Iberville Parish, Louisiana, approximately 6 miles north of Bayou Sorrel, Louisiana.

DOCUMENTS REVIEWED

I am basing my decision primarily on the following documents describing the analysis of the cost and effectiveness of the Remedial Alternatives for the Bayou Sorrel site.

Environmental Protection Agency, 1985. "Remedial Investigation Report, Bayou Sorrel Site, Bayou Sorrel, Louisiana." Volumes I and II. Prepared by CH_2M Hill.

Environmental Protection Agency, 1986. "Endangerment Assessment, Bayou Sorrel Site, Bayou Sorrel, Louisiana." Prepared by Life Systems, Inc.

Environmental Protection Agency, 1986. "Feasibility Study Report, Bayou Sorrel Site, Bayou Sorrel, Louisiana." Prepared by CH_2M Hill and SRW, Inc.

Summary of Remedial Alternative Selection (Attached)

Summary of Public Comments Received During Public Comment Period and Agency Response (Attached)

DESCRIPTION OF THE REMEDY

The Feasibility Study evaluated alternative treatment technologies including incineration and biological treatment. These technologies were not retained due to engineering impracticability (a detailed discussion can be found in the Summary of Remedial Alternative Selection).

- Regrading of the site to control runoff, limit cap erosion, limit surface water ponding and divert storm water from waste areas.
- Former disposal areas will be covered with RCRA top-soil/geomembrane/clay caps

- A sand/geofabric pore water drainage layer will be installed above the wastes and below the cap. This layer will be connected to a system of pipes, manholes, pumps and tanks which will collect and store the liquids from this drainage layer.

- A venting system will be included in the cap to reduce the buildup of methane and other gases beneath the cap.

- All miscellaneous wastes outside currently capped areas would be consolidated under the new caps for grading and fill purposes or disposed of at an off-site facility.

- A slurry wall approximately 30 feet deep (actual depth to be determined during final design) would be installed around the former landfill area. Also, a shallow slurry wall will be constructed around the former pond 4 area.

- All capped areas will be fenced to restrict access to disposal areas. Gravel access roads will be constructed around fenced areas to allow continued recreational use of adjacent lands and borrow lake while diverting traffic around and away from the disposal areas.

- Installation of a groundwater monitoring system to monitor the effectiveness of the remedy.

Decision

Consistent with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the National Oil and Hazardous Substances Contingency Plan (40 CFR Part 300), I select the remedy described above for the Bayou Sorrel site. I have determined that this remedy is cost-effective and is protective of public health and welfare and the environment. The action will require operation and maintenance to maintain the effectiveness of the remedy. Since wastes will be left on-site, the remedial action will be reviewed every five years to assure that the remedy is still protecting public health and the environment. The State of Louisiana has been consulted on the remedy. I have considered Section 121 of the Superfund Amendments and Reauthorization Act of 1986 (SARA), including the cleanup standards thereof, and certify that the portion of the remedial action covered by this Record of Decision (ROD) complies to the maximum extent practicable with Section 121 of CERCLA (as amended by Section 121 of SARA).

If negotiations are successful, potentially responsible parties (PRPs) will enter into a Consent Decree with EPA authorizing the PRPs to implement the remedial action. In the event that negotiations are unsuccessful, litigation will be pursued by EPA and the Department of Justice in an effort to secure performance of the remedial actions.

11. 14. 1986
Date

Frances E. Phillips
Acting Regional Administrator

Summary of Remedial Alternative Selection

BAYOU SORREL SITE
Iberville Parish, Louisiana
March 1986

Site Location and Description

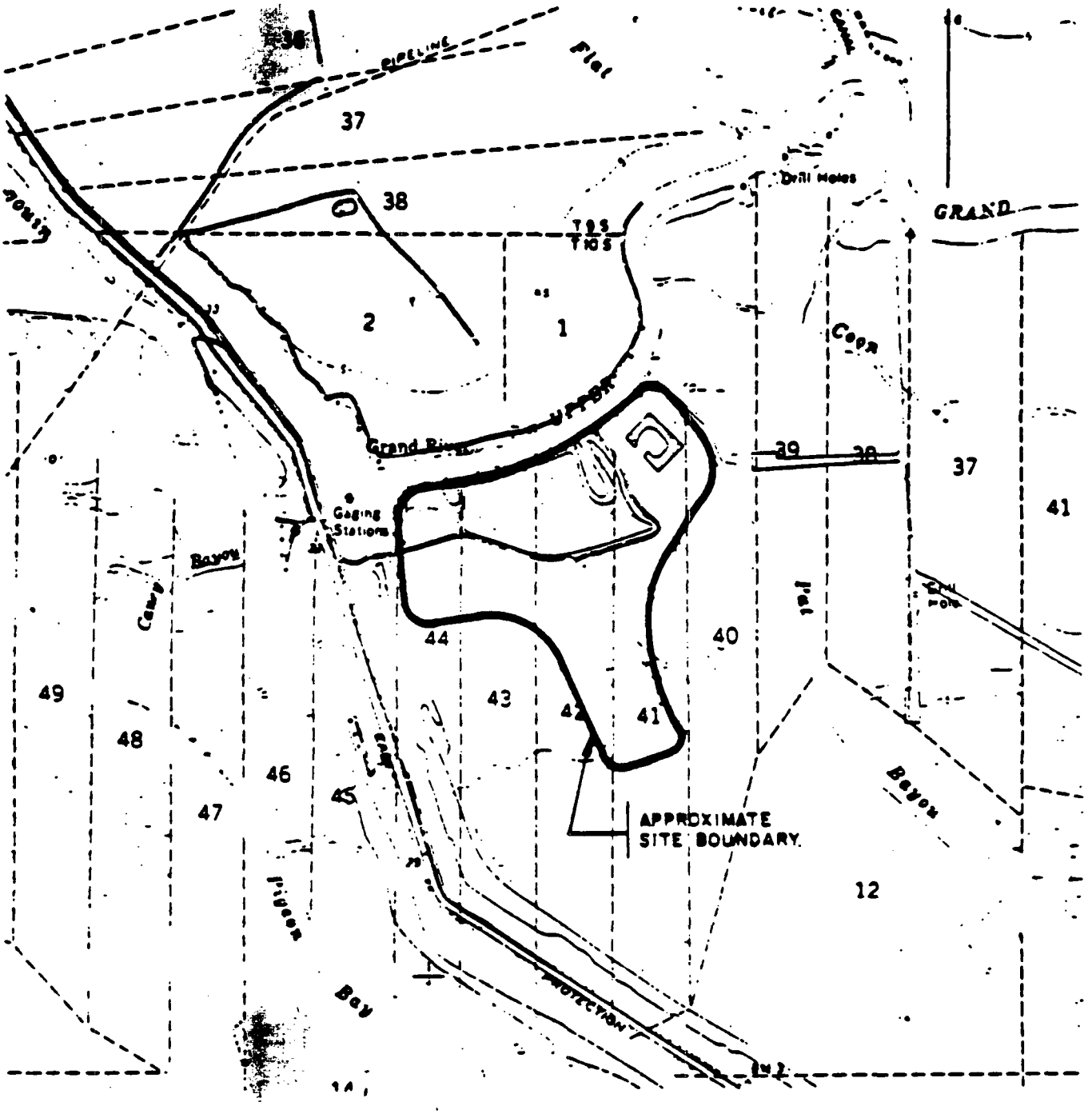
The Bayou Sorrel Site is located in Iberville Parish, Louisiana, approximately 20 miles southwest of Baton Rouge, Louisiana, about six miles northwest of the town of Bayou Sorrel (Figure 1). The west border of the site is bound by a man-made drainage feature called "Borrow River". About 100 yards west of Borrow River is the Atchafalaya Basin Protection Levee, while the north and east sides of the site are bound by the Upper Grand River and Pat Bayou, respectively. Undeveloped swamp land is adjacent to the site on the south (Figure 1). Access to the site from the north is along the unpaved levee road 14 miles south of its intersection with Interstate 10 at Ramah, Louisiana, while access from the south is along the same unpaved levee road six miles north of the town of Bayou Sorrel. The Upper Grand River provides barge access to the site.

The Bayou Sorrel Site, as shown on Figure 2 is a "T" shaped, relatively flat parcel of land encompassing about 265 acres. Approximately 50 of the 265 acres were actually used for waste disposal. The waste disposal areas consist of four landfills including the spent lime cell and the crushed drum cell, four covered liquid waste ponds, and one land farm. All of the disposal areas have been covered with natural soils and contoured as part of the Louisiana DNR regulated closure of the site in 1978 and 1979. Ponds 1,2 and 3 and Landfills 1 and 2 are shown on Figure 2. These disposal areas are characterized by their slightly mounded soil caps which have scattered areas without vegetation. Pond 4 exhibits a very distinguishable soil cap. A 50 acre lake and one acre pond, probably former borrow pits, are situated along the north border of the site.

Apart from disposal areas, the site is generally covered by dense brush and trees. The site (particularly the south end) and surrounding areas can best be described as having marshy bayou-type environment and are prone to periodic flooding and poor drainage.

Site History

The Bayou Sorrel Site began operation in early 1977. It was operated by Environmental Purification Advancement Corporation (EPAC). A sister firm, CLAW, Inc. (Clean Land Air Water) operated an injection well approximately six miles south of the site, in the town of Bayou Sorrel. That well is still operated, presently by others not associated with the former operation of the Bayou Sorrel Site.



SOURCE: (1) U.S.G.S. 7.5' Topographic Map Grand Lake, Quadrangle, Louisiana, Dated: 1969, Photo-revised: 1980, Scale: 1" = 2,000'.

FIGURE 1

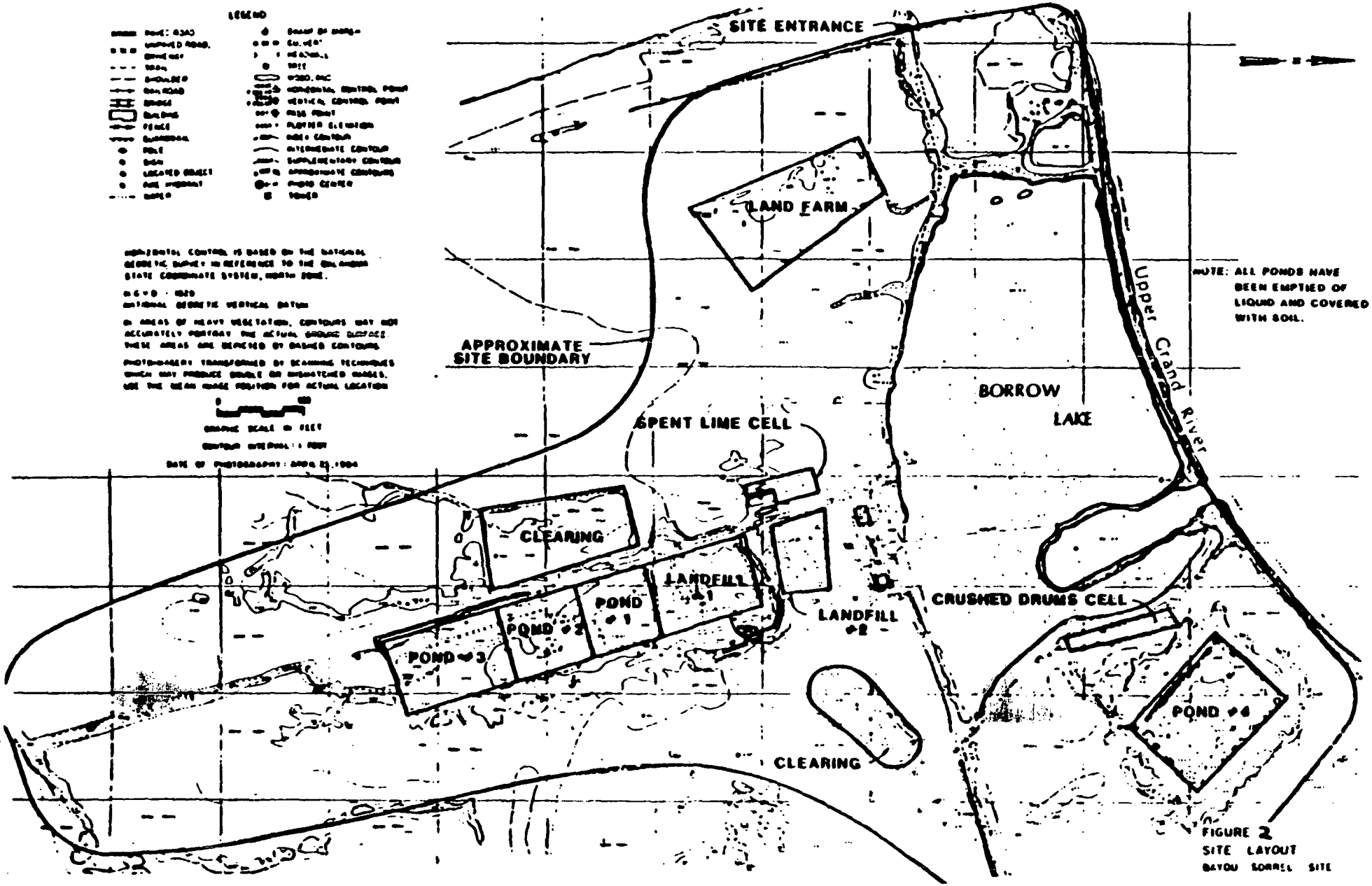


FIGURE 2
SITE LAYOUT
BAYOU SORREL SITE

EPAC operations included landfarming, open liquid impoundments, drum burial, and landfilling of "chemically fixated" wastes. Louisiana Department of Environmental Quality (LDEQ) officials report that all of these except the open pond were permitted by the State. The fixation process is unknown but may have included lime, cement, and native soils. EPAC was supposedly a separate operation from CLAW. However, court testimony by former employees suggests that wastes were diverted from the injection well to the EPAC site when process problems at the well caused a bottleneck. Therefore, both injection-well waste records and EPAC records were included in summarizing wastes possibly present at the site.

In the summer of 1978, a truck driver died at the site. The coroner's report stated the likely cause of death as hydrogen sulfide inhalation. Apparently the liquid wastes he was unloading were incompatible with wastes in the receiving pond, thus creating hydrogen sulfide gas. State and Federal regulatory officials inspected the site following the above incident. The investigation revealed the presence of large open, unpermitted ponds containing unknown materials. As a result of the governmental investigation, the 18th Judicial District Court ordered the closure of the site to eliminate all health hazards.

Closure activities began in September 1978, and were overseen by the State. Closure activities consisted of the following:

1. Dewatering by spray evaporation

2. Transfer of residues from Ponds 1 through 3 to Pond 4 (LDEQ officials report that this activity may have been a partial removal only).

3. Filling in the ponds with native soils and an admixture to Pond 4.

4. Contouring the filled ponds.

During the transfer of material to Pond 4 from Ponds 1-3, there may have been some spill-over of material to the periphery of Pond 4. Closure activities were completed in the spring of 1979, and the site was placed on inactive status by EPA later that year. The quantity of wastes remaining on site was estimated to be 1 million cubic feet (36,400 cubic yards) (RI report).

After closure, the State received complaints about odor and surface contamination in the swamp south of the site. The State contracted Resource Technology, Inc. in 1981 for a preliminary site investigation, and a further investigation by Woodward-Clyde Consultants was completed in 1982. These studies included installation of a total of 12 groundwater monitoring wells, although only three of these were sampled. Groundwater data were inconclusive. Some evidence of surface pesticide contamination was also collected.

Based on the information obtained during these site investigations, the Bayou Sorrel Site was added to the National Priority List of Superfund sites on December 20, 1982. The listing action provided the mechanism for the Environmental Protection Agency (EPA) to perform a Remedial Investigation (RI) to determine the nature and extent of wastes at the site.

The final Remedial Investigation Report was completed in December 1985, and the Feasibility Study Report completed in February 1986.

Current Site Status

The Remedial Investigation (RI) field activities at the Bayou Sorrel site were conducted in two phases. Phase I activities from March to May 1984 included collecting groundwater, surface water, sediment, soil, and biological samples. Phase II activities were conducted in March 1985 and consisted of resampling of onsite monitoring wells.

The results of the RI along with reviews of site operating records, State files and Potentially Responsible Parties (PRP) 104(e) responses allowed the site to be characterized in terms of:

- Wastes present
- magnitude and extent of contamination;
- rate and direction of waste migration;
- target receptors including population at risk, threatened resources, and sensitive ecosystems;
- site geology, and
- site surface water and ground water hydrology.

The following is a summary of the site investigation. The top stratum of the site is approximately 70 feet thick and consist mainly of silts and clays with hydraulic conductivity ranging from 10^{-8} to 10^{-4} cm/sec. One lenticular silt sand bed has been identified within the top stratum with hydraulic conductivity ranging from 10^{-5} to 10^{-3} cm/sec.

Beneath the top stratum are thick deposits of sand, gravel, and silt which may extend to 700 feet below land surface. These coarser sediments comprise the only regional aquifer in the parish and are referred to as the Plaquemine aquifer. Groundwater withdrawals from the Plaquemine aquifer in the vicinity of the site are minimal due to the low population density and marginal groundwater quality. The Office of Public Works of the Department of the State of Louisiana maintains a computer file of water wells in the area including those wells on file by the U. S. Geological Survey. This inventory shows no wells within two miles of the waste site. ERM-Southwest (1984) conducted a field survey of water wells and located two wells within a two-mile radius of the site. These wells were used at local fishing camps for washing only and not for potable supply. Water sample analyses from these two wells exhibited poor water quality with TDS of about 2,000 mg/l, most of which was dissolved chlorides at about 1,000 mg/l.

The Plaquemine aquifer is hydraulically connected to the main channel of the Mississippi River which cuts through the confining top stratum. Stage fluctuation in the river controls head distributions and consequently flow direction in the aquifer. During most of the year, heads in the aquifer are above land surface in the vicinity of the site.

The primary surface water features in the area include the following:

- The Upper Grand River which borders the Bayou Sorrel Site on the north and flows to the west and empties into an unnamed borrow river which flows to the south. The borrow river borders the site on the west.

- Pat Bayou borders the Bayou Sorrel site on the east and drains in a southerly direction into Pat Bayou.

- The southern portion of the site is bordered by back water swamp which covers portions of the site much of the year.

- There are an unnamed borrow lake (approximately 50 acres) and pond (approximately 1 acre) located on the northern portion of the site.

None of these features appear to have been impacted by the Bayou Sorrel site. Runoff generally flows to the south and east, mostly to Pat Bayou and from there to Pat Bay. Most of the site would be inundated by the 100 year flood caused by backwater from the Borrow River and Upper Grand River.

To evaluate the nature and distribution of waste at the site, soil and core samples, groundwater samples, surface water samples, sediment samples, and biological samples were collected for laboratory analyses. Based on 104(e) responses and other site records, wastes disposed at the site during its active life were of the following types:

° Process wastes from pesticide/herbicide manufacture; these include distillation residues, contaminated packaging, and miscellaneous wastes;

° Sulfide-containing wastes (scrubber blowdown and spent caustic) from hydrocarbon processing and exploration activity;

° Spent wash solutions from boiler-cleaning and process equipment-cleaning contractors.

The relative quantities of wastes disposed of at the site is unknown, but the total quantity was estimated to be approximately 1,000,000 ft^3 from Louisiana Department of Natural Resources files.

Some localized surface soil contamination has been found at the site, especially at the south end of the site. This contamination includes herbicide and other organic compounds. Some waste materials, including some which may liberate hydrogen sulfide gas, were found under a thin layer of soil outside of the capped area over pond number 4. Similar wastes are found in pond 4 itself.

During the 1978-79 closure activities the volume of on-site ponds was reduced by enhanced evaporation and landfarming of the pond supernatant. The remaining contents were then solidified with soil and other additives, and the ponds were covered with on-site soil. Because of these closure techniques, there is estimated to be close to 1,000,000 yd^3 of contaminated soil and waste at the site.

Some inconsistent data indicate the possibility of organic contamination of shallow groundwater but at very low levels. No organic constituents were noted in GC/MS analyses of samples from the Plaquemine aquifer beneath the site, except for a single unknown compound at 12ppb from a sample from well 11-D. Contamination of this aquifer by the site appears very unlikely due to the upward hydraulic gradient.

Organic compounds were reported from seven onsite shallow wells for compounds not readily explainable as being derived from laboratory contamination or well construction materials. All of the reported compounds are either reported at very low ppb levels, were present in laboratory blanks at low levels, and/or were not detected in duplicate samples or analyses by ERM-Southwest.

In a study completed in November 1984, by the Bayou Sorrel Task Force (BSTF), 30 buildings were located within two miles of the site. Only three of these buildings were found to be year-round residences. Most buildings in the area are hunting or fishing camps. The closest community to the site is the town of Bayou Sorrel, approximately six miles southeast of the site.

The population potentially at risk is:

- Hunters or fishermen at or near the site.
- Petrochemical workers using the site to gain access to their wells.

Enforcement

State and Federal regulatory officials inspected the Bayou Sorrel site following the death of a truck driver at the site in the summer of 1978. The inspection revealed the presence of large, open, unpermitted ponds containing unknown materials.

As a result of the governmental investigation, the 18th Judicial District Court ordered the closure of the site to eliminate all health hazards.

In the fall of 1982, EPA identified approximately 20 Potentially Responsible Parties (PRPs) for the Bayou Sorrel site. These 20 PRPs were notified of their potential liability and offered the opportunity to participate in remedial activities. In the spring of 1983, approximately 70 additional PRPs were identified and also sent notice letters. None of the PRPs would agree to conduct the necessary studies and implement the resultant remedial activities that were identified by these studies. A group of PRPs did, however, offer to conduct the Remedial Investigation and Feasibility Study (RI/FS) at the site but would not agree "up-front" to implement the selected remedy.

Independent of the EPA investigation, representatives of the PRPs began remedial investigation activities in October 1983. The PRP activities are described in other reports. To the extent possible, the EPA activities were coordinated with those of the PRP's to minimize duplication of effort.

A FS completed by the Bayou Sorrel Task Force in February 1985, recommended a remedy similar to EPA's clay cap alternative, which the PRPs offered to implement.

Alternatives Evaluation

Site specific remedial objectives were established prior to the collection of RI data for the receptor media indentified at the site. The FS developed by CH2M Hill and SRW Inc. developed these objectives which follow:

- Minimize the threat to public health, if any, from use of or contact with onsite surface water bodies which include the lake and small pond, as well as the back swamp in the wet season. Protect the environmental quality of these water bodies from degradation due to contaminants.

- Minimize the threat to public health from use of or contact with off-site surface water bodies which include the back swamp, the Upper Grand River, Grand River, Pat Bay, and Pat Bayou, and protect the environmental quality of these water bodies from degradation due to contaminants.

- Minimize the threat to public health from direct use of the shallow groundwater and protect the quality of the Plaquemine Aquifer and surface water bodies which might receive discharges from the shallow groundwater.

- Minimize adverse effects of present and potential users of the Plaquemine Aquifer from contaminants migrating from the site.

- Isolate contaminated materials from direct contact with surface soils and sediments to minimize migration of contamination.

- Limit the potential for air releases from the site which would have adverse effects on human health and limit onsite concentrations of hydrogen sulfide, cyanide, and other hazardous air pollutants to within OSHA standards.

Based on the data collected to date, active remediation will not be required to meet all of the objectives. The objectives serve as the basis for the environmental assessment in the remedial alternatives evaluation. By combining the applicable remedial action technologies and considering the pathways of migration in accordance with 40 CFR 300.68(f), 13 remedial alternatives were developed for the Bayou Sorrel Site. Table 1 lists the alternatives, along with the technologies they include, and the pathways of migration.

The remedial action alternatives developed included the following categories:

- No Action/Limited Action Alternatives
- Alternatives that Meet the Objectives of CERCLA
- Alternatives that Exceed All Applicable Standards
- Alternatives that Meet All Applicable Standards
- Alternatives that Address Offsite Disposal

TABLE 1

BAYOU SORREL SITE
LIST OF REMEDIAL ALTERNATIVES DEVELOPED FOR SCREENING

Alternative	Description	Pathway of Contaminant Migration: Soil/Sediment Waste	Pathway of Contaminant Migration: Shallow Groundwater	Remedial Technologies Included
1	No Action	N/A	N/A	None
2	Limited Action	X	--	Regrading, topsoil, seeding, offsite disposal of surface waste, fencing, burrowing animal control, groundwater monitoring, construction of diversion roadway to direct traffic around disposal areas.
3	Clay Cap (Onsite Materials)	X	--	Regrading, cap, gas venting, topsoil, seeding, offsite/onsite disposal of surface waste, onsite disposal of contaminated soils, fencing, burrowing animal control, groundwater monitoring, construction of diversion roadway to direct traffic around disposal areas.
4	Clay Cap (Offsite Materials)	X	--	Regrading, cap, gas venting, topsoil, seeding, offsite/onsite disposal of surface waste, onsite disposal of contaminated soils, fencing, burrowing animal control, groundwater monitoring, construction of diversion roadway to direct traffic around disposal areas.
5	Geomembrane Cap	X	X	Regrading, cap, synthetic membrane, drainage layer, gas venting, topsoil, seeding, offsite/onsite disposal of surface waste, onsite disposal of contaminated soils, fencing, burrowing animal control, groundwater monitoring, construction of diversion roadway to direct traffic around disposal areas.
6	Geomembrane Cap with Slurry Wall	X	X	Slurry wall, regrading, pressure relief trench, seepage collection system, off-site disposal of seepage, cap, synthetic membrane, drainage

Table 1 (cont'd)

Alternative	Description	Pathway of Contaminant Migration: Soil/Sediment Waste	Pathway of Contaminant Migration: Shallow Groundwater	Remedial Technologies Included
				layer, gas venting, topsoil, seeding, offsite/onsite disposal of surface waste, onsite disposal of contaminated soils, fencing, burrowing animal control, groundwater monitoring, construction of diversion roadway to direct traffic around disposal areas.
7	Offsite Material Cap with Slurry Wall	X	--	Slurry wall, regrading, pressure relief trench, seepage collection system, off-site disposal of seepage, cap, gas venting, topsoil, seeding, offsite/onsite disposal of surface waste, onsite disposal of contaminated soils, fencing, burrowing animal control, groundwater monitoring, construction of diversion roadway to direct traffic around disposal areas.
8	Onsite RCRA Landfill	X	X	Waste removal, fill placement, membrane liner, leachate collection/detection system, cap, gas venting, topsoil, seeding, groundwater monitoring.
9	Offsite RCRA Landfill	X	X	Waste removal, haul to existing permitted offsite disposal facility, backfill, top soil, seeding, groundwater monitoring, slurry wall, injection well disposal.
10	Onsite Incineration	X	X	Waste removal, incineration, backfill, topsoil, seeding, groundwater monitoring, slurry wall, injection well disposal.
11	Offsite Incineration	X	X	Waste removal, haul to existing permitted incinerator, backfill, topsoil, seeding, groundwater monitoring, slurry wall, injection well disposal.
12	Onsite Biotreatment	X	--	Waste removal, biological treatment of waste, sludge disposal, topsoil, seeding, groundwater monitoring, slurry wall, injection well disposal.
13	Land Treatment	X	--	Waste removal, landfarming, backfill with treated soils, topsoil, seeding, slurry wall, injection well disposal.

INITIAL ALTERNATIVE SCREENING

Each remedial action alternative developed was evaluated and screened in accordance with the NCP 40 CFR 300.68 (g) and (h). The initial screening was based on the following criteria:

Effectiveness

Each alternative was evaluated for its effectiveness in protecting public health, welfare and the environment.

Engineering Feasibility

Each alternative was evaluated in terms of the site specific waste characteristics and the feasibility of the alternative to mitigate the site specific problems.

Cost

Comparative cost estimates were prepared to assess the relative order-of-magnitude cost for each of the remedial alternatives.

Based on the initial screening of alternatives, the following alternatives were retained for detailed evaluation in accordance with the NCP, 40 CFR 300.68 (h).

- No Action
- Clay cap with onsite materials
- Geomembrane cap
- Geomembrane cap with slurry wall
- Source Removal with onsite incineration
- Source Removal with offsite disposal in a secure landfill

In addition to their alternatives listed above, the alternative recommended by ERM Southwest in the FS Report prepared for the BSTF was evaluated in detail.

Following the establishment of remedial objectives and development of general response actions to meet the objectives, remedial action technologies were developed within the general response actions. The general response actions and associated remedial technologies were evaluated primarily for technical feasibility relative to site characteristics, applicability, and also for the following criteria:

- Environmental
- Public health
- Institutional criteria
- Cost

Table 2 lists the general response actions considered and the associated remedial action technologies.

TABLE 2

BAYOU SORREL SITE
GENERAL RESPONSE ACTIONS AND ASSOCIATED REMEDIAL TECHNOLOGIES

Response Action	Technologies
No Action	None
Limited Action	Some monitoring and regrading
Containment	Capping; groundwater containment barrier walls; bulkheads; gas barriers
Pumping	Groundwater pumping; liquid removal; dredging
Collection	Sedimentation basins; French drain; gas vents; gas collection system
Diversion	Grading; dikes and berms; stream diversion ditches; trenches; terraces and benches; chutes and downpipes; levees; seepage basins
Complete Removal	Drum grappling; excavation of soils, sediments and buried waste, pumping of surface water, removal of waste transport pipes
Partial Removal	Drum grappling; excavation of soils and sediments; removal of waste transport pipes
Onsite Treatment	Incineration; solidification; land treatment; biological, chemical, and physical treatment
Offsite Treatment	Incineration; biological, chemical, and physical treatment
In-Situ Treatment	Permeable treatment beds; bioreclamation; soil flushing; neutralization; landfarming
Storage	Temporary storage structures
Onsite Disposal	Landfills; land application
Offsite Disposal	Landfills; surface impoundments; land application; deep well injection
Alternative Water Supply	Cisterns; above-ground tanks; municipal water system; individual treatment devices
Relocation	Physical relocation of affected residents

TABLE 3

BAYOU SORREL SITE

APPLICABLE REMEDIAL ACTION TECHNOLOGIES

General Response	Technology
1. No Action	None
	Monitoring
2. Containment	CAPPING:
	Onsite Clay
	Offsite Clay
	Synthetic Membrane
	Multilayered System
	GROUNDWATER BARRIERS:
	Circumferential Placement of Soil-Bentonite Slurry Wall
	Cement-Bentonite Slurry Wall
	GAS BARRIERS:
	Synthetic (See Collection)
3. Pumping	GROUNDWATER PUMPING:
	None
	LIQUID REMOVAL:
	None
	DREDGING:
	None
4. Collection	SURFACE WATER:
	Seepage Basins
	Sedimentation Basins
	SUBSURFACE DRAINS:
	French Drains
	Dual Media Drains
	GAS:
	Passive Pipe Vents
	Passive Trench Vents
	Active Extraction

General Response	Technology
5. Diversion	GRADING
	REVEGETATION: Grasses Certain Legume Species
	SURFACE WATER: Dikes and Berms Ditches, Trenches and Diversions Seepage Basins Sedimentation Basins Levees Floodwall
6. Complete Removal	
	ALL CONTAMINATION: Dragline Backhoe Industrial Vacuum Drum Grappler
7. Partial Removal	
	AREA OR CONCENTRATIONS
8. Onsite and Offsite Treatment	
	INCINERATION: Rotary Kiln
	SOLIDIFICATION Lime Based
	LAND APPLICATION
	BIOLOGICAL TREATMENT: Activated Sludge Trickling Filters Powdered Activated Carbon
	CHEMICAL TREATMENT: Neutralization Precipitation Carbon Adsorption

General Response	Technology
	PHYSICAL TREATMENT: Flow Equalization Flocculation and Sedimentation Oil/Water Separator Air Stripping Steam Stripping Filtration Sludge Dewatering Removal
9. In-Situ Treatment	CONTAMINATED MATERIALS: Bioreclamation Permeable Treatment Beds
10. Storage	Temporary
11. Onsite Disposal	Landfill
12. Offsite Disposal	Landfill Deep Well Injection

Data collected during the RI were evaluated with respect to each technology to evaluate its site specific applicability. This evaluation was based on:

- Site geology, hydrogeology, and soils
- Waste characteristics (compatibility, ignitability, associated hazard)
- Technology performance and reliability
- Technology implementability (construction, operation and maintenance)

Site applicable remedial action technologies which survived the technology screening are listed in Table 3.

The applicable technologies were combined into comprehensive remedial action alternatives that will mitigate the threat to human health and environment posed by the site. The formulation and refinement of the remedial action alternatives follows the requirements of the NCP as set forth in 40 CFR 300.68 (f). Each alternative consists of one or more remedial activities which focus on achieving the remedial action objectives for the site.

As discussed earlier the objective of the remedial action alternatives at the Bayou Sorrel Site is to prevent or minimize the migration of contaminants from onsite sources and to prevent direct contact with the contaminated media. This objective addresses the following site-specific problems:

- Contaminated surface soils
- Shallow groundwater-possible present or future contamination
- Seeps in the existing cap area
- Waste outside the cap areas
- Cap erosion and inadequate cover
- Seasonal flooding of the area
- Inadequate site restriction

The methodology used to develop the remedial action alternatives for the Bayou Sorrel Site follows the structure presented in "Guidance on Feasibility Studies Under CERCLA," in accordance with the NCP. The steps consist of the following:

1. Identify Site Problems - The site problems and contamination exposure pathways are identified in the Endangerment Assessment (EA) and the Remedial Investigation (RI) reports.

2. Identify General Response Actions - Based on the information collected in the RI and the problems defined, general classes of response actions are identified. The response actions address the site problems and the cleanup goals and objectives.

3. Identify and Screen Technologies - Applicable technologies for each general response action are identified in the FS report. The site data is reviewed to aid in the identification of compatible technologies that are effective in mitigating the site-specific and waste-specific problems. The screening criteria for the technologies included environmental and public health effects, site-related considerations, and cost. Those technologies deemed incompatible, technically inappropriate, or cost prohibitive were eliminated from further consideration.

4. Develop Alternatives by Combining Technologies - The technologies which pass the screening process are assembled into alternatives which address the pathways of migration in accordance with 40 CFR 300.68 (d). The technologies are combined into alternatives based on acceptable engineering practice and project remediation goals. In accordance with 40 CFR 300.68 (f), the most applicable technologies are assembled into comprehensive remedial action alternatives for the site. This involves selecting remedial action for each pathway of migration and integrating them so that at least one remedial action alternative is developed for each of the following five categories:

a. No Action;

b. Offsite storage, destruction, treatment or secure disposal of hazardous substances at a facility approved under RCRA and all other applicable USEPA, State, and local standards;

c. Onsite remediation that attains all applicable or relevant Federal, State or local public health or environmental regulations, standards, guidelines, and advisories;

d. Remediation that exceeds all applicable or relevant Federal, State, or local public health and environmental raegulations, standards, guidelines, and advisories; and

e. Remediation that meets CERCLA goals of preventing or minimizing present or future migration of hazardous substances and protects human health and the environment, without necessarily complying with other environmental and/or public health regulations.

The thirteen remedial alternatives that were developed for the Bayou Sorrel site were evaluated and screened in accordance with the NCP [40 CFR 300.68 (g) and (h)]. The initial screening was based on:

- The Effectiveness of the alternative in protecting public health, welfare and the environment;
- the engineering feasibility of the alternative, and
- cost of the alternative.

The alternatives which passed the initial screening were refined and developed in detail for costing purposes pursuant to the NCP [40 CFR 300.68 (h) (2) (i)]. The following criteria were utilized to technically evaluate each alternative.

- Performance
- Reliability
- Engineering Implementability/Constructability
- Public Health and Welfare
- Environmental Impacts
- Institutional Factors
- Costs

A description of the detailed evaluation screening criteria follows:

Performance

The performance criterion evaluates the alternatives in terms of their effectiveness and useful life. Effectiveness relates to how well the alternative meets the objectives of ultimate remediation to prevent or minimize release of contamination. Useful life relates to the period of time that the effectiveness can be maintained.

Reliability

The reliability of an alternative is assessed on the basis of operation and maintenance and demonstrated performance. Operation and maintenance considerations include labor availability, frequency, necessity, and complexity. Demonstrated performance is characterized by proven field performance, low probability of failure, and proven pilot scale testing.

Engineering Implementability/Constructability

The engineering implementability of each alternative is assessed based on ease of installation, time to implement the alternative, and time to achieve the benefits of the alternative. Constructability refers to the applicability of the alternative to site conditions, external conditions such as permits and access to disposal facilities, and equipment

availability. Time to implement includes time for treatability studies, design, and construction. Beneficial results are defined as a reduction of contamination or degree of exposure necessary to obtain remediation goals.

Public Health and Welfare

The public health and welfare criterion evaluates the safety of each alternative during construction and operation and upon failure. The evaluation covers safety of community, environment and workers during installation and operation. It also considers effects in the event of failure after remedial action implementation.

Environmental Impacts

The environmental impact criteria are evaluated in terms of short-term and long-term effects. The short-term effects are generally construction-related and refer to site pollution, site alteration, and construction debris. Site pollution refers to odor, noise, air emissions, surface water and/or groundwater contamination caused by construction activities. Site alterations relate to wildlife habitat alteration, historic site alteration, and disruption of households, businesses and services. The construction debris evaluation considers the amount and type of debris and requirements for disposal.

The long-term impacts are also evaluated for site pollution and site alteration. The site pollution criteria consider the odor, noise, air pollution, surface and/or groundwater contamination after remedial action implementation. Long-term site alteration considers wildlife habitat alteration, threatened and endangered species, use of natural resources, parks, transportation, and urban facilities; historic site alteration; relocation of households, businesses, and services; and aesthetic changes.

Institutional Factors

The institutional evaluation considers political jurisdictions, land acquisition, and land use and zoning. Alternatives are evaluated in terms of ease of satisfying applicable institutional criteria. In accordance with the NCP [40 CFR 300.68 (h) (2) (ii)], alternatives which pass initial screening must be technically and economically evaluated to develop the most cost-effective remedial alternative. To perform a detailed cost analysis, the various major components of each alternative must be evaluated and estimates of expenditures required to complete each measure developed in terms of capital and operation and maintenance costs. An indepth discussion of the evaluaton process can be found in Section 5 and Appendix C of the FS report. Table 5 provides information on capital costs and present worth of the remedial alternatives for the Bayou Sorrel site.

Consistency with other Environmental Laws

In accordance with 40 CFR 300.68 (f), the most applicable technologies are assembled into comprehensive remedial action alternatives for the site. This involves selecting remedial actions for each pathway of migration and integrating them so that at least one remedial action alternative is developed for each of the five categories:

a. No Action;

b. Offsite storage, destruction, treatment or secure disposal of hazardous substances at a facility approved under RCRA and all other applicable USEPA, State, and local standards;

c. Onsite remediation that attains all applicable or relevant Federal, State or local public health or environmental reagulations, standards, guidelines and advisories;

d. Remediation that exceeds all applicable or relevant Fedral, State, or local public health and environmental regulations, standards, guidelines, and advisories; and

e. Remediation that meets CERCLA goals of preventing or minimizing present or future migration of hazardous substances and protects human health and the environment, without necessarily complying with other environmental and/or public health regulations.

Within each category, remedial actions are developed which are cost effective, and have relatively high technical and public health and environmental value in comparison to other combinations of retained technologies.

TABLE 5

Capital Cost and Present Worth
for Remedial Alternatives
Bayou Sorrel Site

Remedial Alternative	Capital Cost** ($ Million)	Present Worth ($ Million)
A. No Action	0	
B1. Clay Cap	15.3	21.3
B2. Geomembrane Cap	16.7	22.2
C. Geomembrane Cap with Slurry Wall	23.2	28.7
D. Onsite Incineration		
- 10 Year Term	82.9	486.0
- 30 Year Term	36.2	214.4
E. Offsite Disposal	556.5	561.6
F. Recommended Alternative by ERM-Southwest	16.6	22.7

The main environmental law pertaining to this site is RCRA. Four of the alternatives developed for the Bayou Sorrel site would comply with RCRA.

These are:

- Geomembrane Cap
- Geomembrane Cap with Slurry Wall
- Offsite RCRA Landfill, and
- On-site incinerator

For any alternative requiring off-site treatment or disposal, a facility in compliance with all applicable laws would be utilized. This would include such things as contaminated storm water or pore water to an injection well (UIC), excavated drums to a landfill (RCRA), etc.

The following elements are common to the three on-site alternatives developed in the FS.

o Regrading site to control runoff, limit cap erosion, limit surface water ponding and divert storm water from waste areas.

o Installation of a geofabric and sand drainage layer and collection system. A two percent crown would be established over the drainage layer using onsite unclassified soils. A clay cap constructed of onsite clayey soils would be placed over the unclassified soils in the crowned areas.

  Construction of the cap would involve the placement and compaction of about 24 inches of clay, maintaining the minimum 2 percent grade. The cap would be graded so that it would be crowned at the center and sloped to drain toward the perimeter at a minimum gradient of about 2 percent. This grade would maintain surface drainage to the cap perimeter while also allowing for settlement due to the compression of the underlying waste and soils. Providing a 2 percent gradient on the surface should increase the runoff coefficient, resulting in a reduced contact time and decreased infiltration.

o A 6-inch thick sand layer would be constructed on the surface of the compacted clay to allow for drainage of the topsoil. This layer would be drained by extending sand drainage channels beyond the capped areas.

o A geotextile filter layer would be installed over the drainage layer to prevent the drainage layer from becoming clogged with fines washed down from the topsoil.

o A system of pipes, manholes, pumps and ponds would be installed to collect and store the seepage from the lower drainage layer.

o The liquids collected would be transported and disposed of appropriately.

- During installation of the clay cap, a gas venting would be installed to reduce the buildup of system methane and other gases beneath the cap. The vented gases would be treated by installation of carbon canisters and periodic air sampling would be performed to evaluate the need for continued or additional treatment.

- The capped areas would be covered with 12-18 in. of topsoil from a suitable onsite borrow area, and seeded to reduce erosion. Installation of non-woven fabric mat may be used in certain areas to reduce the erosion potential prior to establishment of vegetation.

- All miscellaneous wastes outside the capped area, i.e. waste transport pipes, waste storage drums from the RI, etc. would be collected and either hauled offsite to a permitted landfill or placed under the capped area, along with any contaminated soils or waste identified during the remediation.

- All regraded areas would be surrounded with a 6-foot high chain link fence to restrict disposal area access.

- Groundwater monitoring of the shallow and deep aquifers would be performed on a semi-annual basis for a period of at least 30 years. The monitoring system will be based on existing site data and current RCRA guidance. The groundwater would be monitored for contaminants previously identified at the site and contaminants expected as a result of the materials disposed of at the site.

- Gravel access roads would be constructed completely around all fenced areas to allow continued recreational use of the adjacent lands and Borrow Lake while diverting the traffic around and away from the disposal areas themselves.

The geomembrane cap alternative, in addition to the items listed above, would include a minimum 30 mil thick HDPE geomembrane over the clay layer of the cap.

The geomembrane cap with slurry wall alternative consists of the measures described for the geomembrane cap alternative with the addition of a slurry wall around the capped areas. This alternative also includes a pressure relief drain system inside the slurry wall to provide an outlet for increased pore water pressure caused by settlement of the cap or seasonal groundwater elevation changes. A system is also included to collect, store and dispose of the seepage collected.

Elements common to both excavation alternatives evaluated by EPA are as follows:

- A road berm would be constructed to elevation 10 to prevent flooding of the waste areas during excavation operations. A cement/ bentonite slurry wall would be installed to an elevation approximately 5 feet below the waste to be excavated. The purpose of this slurry wall would be to promote stability of the hole and to minimize inflow of groundwater during excavation.

- A temporary waste storage/dewatering pad would be constructed, with a synthetic membrane over a graded onsite surface. The membrane would be covered with a minimum of 18 inches of sand and gravel which would serve as a leachate collection system. Sides of the membrane would be raised at the pad's perimeter to contain leachate.

- A system of pipes, pumps, and ponds would be installed to collect and store the drainage from the excavation and the storage/dewatering pad. The contaminated water collection ponds would be situated south of the waste excavation areas. These ponds have been sized to contain the surface runoff from the site area during a 10 year, 6 hour design storm. The pond south of the landfill cells and Ponds 1 to 3 would contain about 4.5 million gallons of runoff and the pond south of Pond 4 would contain about 2 million gallons. The liquids collected would be transported and disposed of in a permitted injection well.

- Excavation of waste and contaminated soils would be performed within the limits of the slurry wall. A bench would be left adjacent to the slurry wall on the inside of the excavation for structural support. Two to one side slopes would be retained below the bench to provide adequate stability against a slope failure into the excavation. Excavated waste would be placed on the storage pad for dewatering.

In addition to these elements, the offsite disposal and on-site incineration alternatives have elements unique to each alternative.

Source Removal with Offsite Disposal

- The surface of the former waste disposal areas would be regraded to control runoff, limit cap erosion, limit surface water ponding, and divert storm water from the waste disposal areas.

- A system of pipes, pumps, and ponds would be installed to collect and store the drainage from the excavation.

- The excavated wastes would be tranported to an offsite permitted RCRA compliant secure facility for ultimate disposal by landfilling. Treatment of the wastes with a 10 percent mixture of lime, kiln dust, or similar material, may be necessary for proper material handling and stability, to facilitate transportation and disposal operations, and to comply with restrictions against land disposal of wastes containing free liquids.

- Upon completion of the excavation in one area, the excavation would be dewatered and backfilled with soil borrowed on site. The backfill would be properly placed and compacted to provide a stable, uniformly graded surface.

- Upon completion of the backfilling operations, the surface would be graded, a seed bed prepared, and appropriate seed sown.

- A short-term monitoring program of the shallow groundwater should be performed on a semi-annual basis for a period of three years. Wells would be installed at the former disposal areas to monitor the performance of source removal.

The following elements are unique to the on-site incineration alternative:

- Wastes would be allowed to dewater on a covered storage pad area, prior to incineration.

- The wastes would be transported to feed hoppers for the onsite incinerator and then burned. The onsite incinerator would be covered to facilitate continuous operation even during the rainy season. The ash would be cooled and disposed of in a state permitted solid waste facility. Cooling of the ash would be accomplished with a Tube Cooler, which is a water-based heat exchanger which prohibits contact of the water with the ash. The water would be cooled using a cooling tower and clarified prior to re-use in a concrete lined settling basin. Because of the nature of the onsite wastes no significant reduction in total volume is anticipated.

- As the process of excavation continued, the excavation would be backfilled with onsite soils borrowed from adjacent areas. The backfill would be properly placed and compacted to provide a stable, uniformly graded top surface. Careful handling of the staged excavation and backfilling process would be required to prevent re-contaminating the backfilled soils. In addition, a sump would be required at an elevation lower than the backfilled area to prevent saturating the soils with contaminated water. The actual sequence and sizing of these operations and facilities would be performed during the design phase.

- Upon completion of the backfilling operations, the surface would be graded, a seed bed prepared, and appropriate seed sown.

- A short-term program of monitoring the shallow groundwater would be performed on a semi-annual basis for an anticipated period of three years. Wells would be installed at each of the disposal areas to monitor the performance of source removal.

Recommended Alternative

40 CFR 300.68 (J) (NCP) States:

"The appropriate extent of remedy shall be determined by the lead agency's selection of the remedial alternative which the agency determines is cost effective (i.e. the lowest cost alternative that is technologically feasible and reliable and which effectively mitigates and minimizes damage to and provides adequate protection of public health, welfare, or the environment)". In addition, EPA policy requires that, as a general rule, a selected alternative remedy attain applicable or relevant standards, with certain exceptions, including interim remedies. Based upon the evaluation of the RIFS, EPA has determined that onsite disposal with a geomembrane cap and a slurry wall around the old landfill areas and pond 4 meets the NCP criteria found at 40 CFR 300.68. This will be the minimum remedy that EPA would accept following negotiations with Responsible Parties for the Bayou Sorrel site.

As discussed in the RI and FS, direct use of shallow groundwater in the area is not documented and contamination of shallow groundwater has possibly occurred but at low levels (<100 ppb) and does not appear to be wide spread. Also, the deeper (Plaquemine) aquifer is under free-flowing artesian condition which results in an upward hydraulic gradient (and resulting upward flow) through overlying soils. Therefore, contaminant transport will be limited to diffusion, which is generally very slow.

To ensure that contaminants are not leaving the former waste disposal areas via the shallow groundwater and to ensure that the Plaquemine aquifer does not become contaminanted, a comprehensive groundwater monitoring program will be conducted. A "trigger" mechanism will be included so that additional remedial actions will be taken if it becomes necessary.

At a minimum, monitoring will continue for 30 years and a decision on the necessity for continued monitoring will be made prior to the end of the 30 year period.

Compliance with Section 121 of the Superfund Amendments and Reauthorization Act of 1986

Under §121 (b)(1) "remedial actions in which treatment which permanently and significantly reduces the volume toxicity, or mobility of the hazardous substances, pollutants, and contaminants is a principle element, are to be preferred over remedial actions not involving such treatment".

RODs signed within 30 days of enactment of SARA must comply to the maximum extent practicable with §121 of CERCLA (§121(g)).

The selected remedy for the Bayou Sorrel site includes a RCRA compliant cap, slurry walls around the most contaminated disposal areas, and extensive groundwater monitoring (described in the next section). In the process of selecting the remedial alternative, a number of remedies were examined in accordance with the National Contingency Plan, 40 CFR 300.68, and either screened or retained for final evaluation under 40 CFR 300.68(h). Although the remedial alternatives were evaluated and a selection made before the enactment of §121 of CERCLA, the screened alternatives would also not be appropriate under the requirements of the current law.

The following examines the rationale used in screening remedial alternatives for the site under the NCP, 40 CFR 300.68, and whether this method resulted in the selection of an appropriate remedy for meeting the intent of §121 of CERCLA to the maximum extent practicable. Those remedies which were evaluated in accordance with the requirements of 40 CFR 300.68(g) "Initial Screening of Alternatives", and are permanent remedies within the intent of §121 of CERCLA, or were retained and evaluated under 40 CFR 300.68(h) "Detailed Analysis of Alternatives" are included.

Permanent remedies evaluated in the Feasibility Study which would comply with the intent of §121:

- †Biological Treatment
- †Land Treatment
- Offsite Incineration
- Onsite Incineration

Remedies which reduce mobility:

- Clay Cap
- Cap with Slurry Walls

Remedies Consistent with the NCP, but which do not comply with §121:

- Excavation and Off Site Disposal

† did not pass intial screening under 40 CFR 300.68(g)

Source Removal with Onsite Biological Treatment

Source Removal with Onsite Land Treatment

These alternative were not retained after screening under 40 CFR 300.68(g). However if effective, both would remove the organic constituents of the waste onsite and so provide permanent remedies.

As viable treatment alternatives, biotreatment and landfarming have not been shown to be effective treatment technologies for the wastes onsite, the probability of failure of either remedy resulting from wastes not amenable to such treatments is high. However, §121(b)(2) states that "the President may select an alternative remedial action meeting the objectives of this subsection whether or not such action has been achieved in practice at any other facility or site that has similar characteristics." A broad interpretation of this section may not allow the probability of failure as sufficient reason for "initial screening" of the alternatives.

§121(b)(1)(D) requires that the remedy take into account "short and long term potential for adverse health effects from human exposure." All of the alternatives that provide source removal require the exvacation of the wastes onsite. During treatment, excavation of the contaminated soils would significantly increase the risks to public health from exposure, and additionally increase the probability of a release from the site.

The biotreatment and landfarming were estimated to require 40 years or more for completion. During these periods wastes would be excavated significantly increasing the risk associated from the site. In light of the risk of failure of these remedies and the greater risks both provide. The promulgation of §121 would not necessitate additional scrutiny of these alternatives.

Excavation with Onsite or Offsite Incineration

These alternatives were not selected as the site remedy under 40 CFR 300.69(i). Both would provide permanent remedies for the site.

Offsite incineration is comparable to onsite incineration, but would create added risks of exposure while the wastes were being transported and require an extended treatment period, approximately 80 years.

Onsite incineration is a proven technology which would permanently destroy the organic constituents of the wastes and therefore reduce the toxicity and mobility of the contaminants. The remaining ash would still have considerable volume and may remain a hazardous waste since metals are present onsite. Incineration of the million cubic yards of wastes would require from 10 years (6 incinerators) to 30 years (2 incinerators) respectively. During this period there would be a significant increase inpotential for adverse health effects from human exposure to the excavated wastes and possible accidential disruption of the incineration leading to increase in the risk of hazardous emmissions.

Incineration increases the risk of exposure to the wastes and to hazardous emmissions for an extended period of time. Additionally, there is the chance that after treatment a hazardous waste would still remain which would require disposal. Incineration as a treatment alternative for this site would not be a required alternative under §121 of CERCLA.

Excavation and Offsite Disposal in a Permitted RCRA Facility

This alternative was not selected as the site remedy under 40 CFR 300.68(i).

Under §121(b)(1), the offsite transport and disposal of hazardous materials without permanent treatment technologies should be the least favorable alternative remedial action where practicable treatment technologies are available. This remedy is therefore unacceptable where other alternatives are available.

RCRA Compliant Clay Cap

RCRA Compliant Clay Cap with Slurry Walls

A RCRA compliant cap and slurry walls with an extended monitoring program was the selected remedy under 40 CFR 300.68(i). The contaminants will remain onsite, and therefore under §121(c) the remedy will have to be reviewed "no less often than every 5 years after the initiation of such remedial action to assure that human health and the environment are being protected by the remdial action being implemented.

Wastes onsite were stabilized with cement kiln dust and lime, and mixed with large volumes of soil. This decreased the mobility of the wastes and reduced the relative toxicity from direct contact with them.

A cap would greatly reduce infiltration from rainwater preventing offsite migration of the contamination. The addition of slurry walls would isolate the wastes, further reducing the possibility of migration into the offsite shallow groundwater. Extensive monitoring associated with the selected remedy would illuminate problems enabling corrective action to be taken expediently.

The remedial investigation for the site did not indicate offsite migration. Endangerment is associated with the potential for a release and direct contact with the wastes. The soils underlying the site are extremely impermeable, successfully limiting migration from the site with only the current closure. Presently, as there is no detected offsite contamination, no Louisiana Environmental Statutes are being violated. All applicable or relevant and appropriate standard, requirement, criteria, or limitations shall be complied with as required for a remedy in which wastes remain onsite under §121(d).

Permanent remedies for the site were screened during the selection process outlined in the NCP 40 CFR 300.68. However, since the permanent remedies for the site do not meet the requriements of §121(b), advent of the new law does not necessitate reevaluating the remedy selection in order to comply with the congressional intent of selecting permanent remedies when it is practicable.

A capping remedy with slurry walls complies to the maximum extent practicable with §121 of CERCLA and therefore is an appropriate remedy for selection within the 30 day period following enactment of SARA as required in §121(g).

COMMUNITY RELATIONS RESPONSIVENESS SUMMARY
ON PREFERRED REMEDIAL ALTERNATIVE
BAYOU SORREL SITE, IBERVILLE PARISH, LOUISIANA

This community relations responsivenes summary is divided into the following sections:

I. Overview - This section discusses EPA's preferred alternative for remedial action, and likely public reaction to this alternative.

II. Background on Community Involvement and Concerns - This section provides a brief history of site background and community interest and concerns raised during remedial planning activities at the Bayou Sorrel site.

III. Summary of Major Comments Received During the Public Comment Period and the EPA Responses to Comments

I. OVERVIEW

In the presentation for the public meeting on February 26, 1986, EPA discussed the remedial alternatives which were examined in the Feasibility Study for addressing the contamination at the Bayou Sorrel site.

After the initial screening of the alternatives, a detailed evaluation was performed on the seven remaining. Except for the no action alternative, all met basic criteria for protecting public health and the environment and all had common components. The alternatives are:

1.	No Action	Est. Cost: - 0 -
2.	Clay Cap	Est. Cost: $ 15.3 Million (capital) $ 21.1 Million (present worth)
3.	Clay Cap with Geomembrane	Est. Cost: $ 16.7 Million (capital) $ 22.4 Million (present worth)
4.	Geomembrane Cap with Slurry Wall	Est. Cost: $ 23.2 Million (capital) $ 28.9 Million (present worth)
5.	Source Removal with Onsite Incineration (10-year timeframe)	Est. Cost: $ 87.7 Million (capital) $ 329.2 Million (present worth)
	(30-year timeframe)	Est. Cost: $ 37.9 Million (capital) $ 155.6 Million (present worth)
6.	Source Removal with Offsite Disposal	Est. Cost: $ 536.2 Million (capital) $ 540.5 Million (present worth)
7.	Clay Cap with Deep Leachate Collection System	Est. Cost: $ 16.2 Million (capital) $ 21.5 Million (present worth)

Based upon the evaluation of the Remedial Investigation and Feasibility Study (RI/FS), the EPA has determined that onsite disposal with a geomembrane cap and a slurry wall around the most contaminated areas is the corrective action of choice. This remedy meets the NCP criteria found in 40 CFR 300.68, and would be the minimum remedy that the EPA would accept following negotiations with Responsible Parties for the Bayou Sorrel site. EPA anticipates that this remedy will meet with a favorable reaction from the public.

BACKGROUND ON COMMUNITY INVOLVEMENT AND CONCERNS

Site Background

The Bayou Sorrel site is approximately 20 miles southwest of Baton Rouge, about 6 miles northwest of the town of Bayou Sorrel. The site is also known locally as "Grand River Pits," due to its proximity to the Upper Grand River on the north. Fifty of the site's 265 acres received wastes. Disposal areas consisted of four liquid waste ponds, four landfills (at least one of which contains drums), and one land farm. Data from water and sediment samples of a 50-acre lake and a one-acre pond on the edge of the site indicate that they were probably borrow pits and not used for disposal. Disposal operations began in early 1977. In the summer of 1978, a truck driver died at the site when liquid wastes dumped from his truck reacted with contents of the receiving pond to create lethal hydrogen sulfide gas. A State of Louisiana District Court ordered the site closed in late 1978. Closure activities, completed in spring 1979, consisted of dewatering, filling, and capping the open ponds. After closure, the State of Louisiana continued to receive complaints about odors and surface contamination in the swamp south of the site. Based on information from investigations performed by the State in 1981 and 1982, the Bayou Sorrel site was added to the Superfund National Priorities List (NPL) in July 1982.

Major Concerns and Issues

Community involvement relating to the Bayou Sorrel site has been strong. Public interest in the site appears to have begun in early 1978. At that time, the Iberville Parish Police Jury notified the Louisiana State Department of Health of its strong objection to the disposal of wastes at the facility. The State Department of Health responded with a letter to the site operators notifying them that disposal of wastes was permitted only with department approval for each specific waste load.

Several local residents formed the Concerned Citizens of Bayou Sorrel in early July 1978. Their first meeting dealt primarily with odors and potential contamination from the hazardous waste injection well located in the town of Bayou Sorrel. Approximately 75 people attended this first meeting. Public concern and interest were substantially elevated when a truck driver was killed at the site on July 25, 1978. A second meeting of the Concerned Citizens of Bayou Sorrel was held in early August of 1978 and was attended by over 200 area residents. Interest of the group expanded to include cleanup of the Bayou Sorrel site (at that time, this group called the site "Grand River Pits").

In the fall of 1978, the only bridge leading to the site was burned to prohibit truck access. An area newspaper alleged that the fire was a result of area residents' frustration with what they perceived as inaction by the State of Louisiana.

In response to continuing citizen complaints, the State of Louisiana, in 1981, conducted a preliminary site investigation and installed wells for long-term monitoring. After the EPA listed the site on its National Priorities List, the Iberville Parish Police Jury passed a resolution to support clean up activities of the Bayou Sorrel site.

In 1979, more than 150 people living in the area filed a civil suit against the owners of the injection well and the Bayou Sorrel site, charging that both had been a nuisance for years and that fumes from the open pits had harmed residents' health.

Activities to Elicit Input and Address Concerns

The Louisiana Department of Environmental Quality (LDEQ) assumed lead responsibility from the Louisiana Department of Health. They responded to numerous telephone calls from area residents concerning the injection well and the Bayou Sorrel site. Subsequently, the EPA conducted site inspections pursuant to the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA).

The EPA issued a press release on March 19, 1984, announcing the start of extensive remedial investigation and feasibility studies (RI/FS). At that time, the Work Plan was made available to the public at the three established strategically located respositories, for their review and study.

Subsequent to the end of the RI/FS, the EPA issued a press release to announce a public meeting held on February 26, 1986, in the Police Jury Room of the courthouse in Plaquemine, Louisiana. This meeting was held to discuss the cleanup alternatives for surface and groundwater contamination at the site.

A public comment period was established from February 12, 1986 through March 5, 1986, during which both oral and written comments were received by the EPA.

Continuing meetings have been held with the Responsible Parties at the Bayou Sorrel site.

III. SUMMARY OF PUBLIC COMMENTS RECEIVED DURING PUBLIC COMMENT PERIOD AND AGENCY RESPONSES.

This public comment period on the Feasibility Study for the Bayou Sorrel Superfund site was originally scheduled from February 12 to March 5, 1986. The last day to receive comments was officially extended to March 15. A public meeting was held on February 26, 1986, in Plaquemine, Louisiana with approximately 80 people in attendance and 22 of those making oral statements or asking questions. Five written statements were received during the comment period. A summary of these comments is provided below.

In addition to the public meeting, a briefing was held for local officials on February 26, 1986. Present at this meeting were officers and members of the Iberville Parish Police Jury and representatives of the Louisiana Department of Environmental Quality, along with EPA and its consultants. The Bayou Sorrel Feasibility Study alternatives were presented to members of the Iberville Parish Police Jury and the possible implementation of the selected remedy by potentially responsible parties was discussed.

Comment #1

(United States Department of the Interior, Fish and Wildlife Service
Mr. Willie Hurdle - Iberville Parish Police Jury)

The U.S. Department of the Interior, Fish and Wildlife Service stated that since the site is surrounded by open water and baldcypress/tupelogum swamp with high fish and wildlife value, since the site is inundated during high water periods, since large amounts of hazardous wastes are at the site, and since the site is only a few feet above the normal water table they recommend that at a minium the geomembrane cap and slurry wall remedy be implemented at the Bayou Sorrel site.

EPA response to comment number #1

The geomembrane cap and slurry wall is one of the on-site remedies currently being considered by EPA. However, the remedial investigation conducted at the Bayou Sorrel site has not confirmed that waste constituents are migrating from former disposal areas via groundwater. EPA feels that a clay cap with a slurry wall around the former land fills and pond 4 only is sufficient to protect human health and the environment. This remedy will also include a mechanism in the monitoring program to determine definitely whether migration is or is not occuring and if so the extent of migration and the effect the migration might have on public health and the environment. If such a remedy is implemented by responsible parties, this mechanism would be included in a legal consent instrument and would allow for additional remedial measures if necessary.

Comment #2

(Ecology Center of Louisiana, Dr. Velma Campbell)

The above comments oppose an on-site remedy (clay cap, geomembrane cap, or geomembrane with slurry wall) because of one or more of the items listed below.

These commentors feel that an in-place remedy is unsatisfactory because:

- If constituents leak from the former waste disposal area, contaminants will not be detected until after materials have escaped containment.
- The monitoring program will end before any contaminants are likely to escape.
- If any contaminants are found in groundwater river or swamps, it would be blamed on the site if wastes remain at the site.
- It is not credible to suggest that any entity will monitor to perpetuity.
- Clay cap alternatives are not disposal alternatives but rather long-term storage.
- Deed restrictions would remove the land from recreation, commerce, development, and natural processes of evaluation.
- The State or community would be left with the long-term burden of oversight.
- Capping as ultimate remediation worsens the original situation because it enshrines in legal agreements the existing non-viable situation it is designed to correct.
- The Louisiana Legislature has determined that the southern part of Louisiana is unsuitable for hazardous waste disposal. Land disposal is to be phased out by 1991. It is inapproprate to propose a remedy that would be illegal if it were a commercial operator.
- The area around the Bayou Sorrel Site is hydrogeologically active and interconnected. In situ percolation rates suggest that the site may leak in terms of feet per year rather than fractions of inches.

EPA Response to Comment #2

The RI/FS conducted at the site by EPA does not indicate that any extensive movement of contamination has occurred. However, the monitoring program designed for any in situ remedy would be designed so that any movement of waste constituents from the containment areas would be detected early. This monitoring plan would have a "trigger mechanism" to ensure that additional remedial work is undertaken if significant contamination is detected.

Even though the monitoring program described in the FS is for a minimum of 30 years, EPA would reevaluate any monitoring program prior to expiration to determine if additional monitoring is necessary.

The site monitoring program will be designed to ensure that contaminants are unable to migrate to surface water (i.e. swamp, lake or river) undetected.

Any monitoring progam implemented at the site by PRPs in conjunction with an onsite remedy will be included in a legal instrument to ensure that monitoring is conducted as scheduled.

Even though an onsite remedy would not result in destruction of wastes and waste constituents, the geology at the site is such that waste migration would not be extensive. The deed restrictions that will be included in an onsite remedy would not entirely remove the Bayou Sorrel site from recreation, commerce, and development. It will of course, limit access to the site, especially the former waste disposal areas, and limit other activities conducted at the site. This will include preventing direct contact with waste disposasl areas, and activities that would disturb the cap and other elements of an onsite remedy.

There is also concern that the State or local community would be left with the burden of long term oversight. EPA will ultimately be responsible for any oversight of remedial activities or maintenance and monitoring activities. As in other areas of environmental concern and at other sites, EPA would rely on the expertise of State officials and other local environmental and health agencies as necessary. In sites where federal money is used for remedial action, CERCLA requires, prior to providing these remedial actions that the State enter into a contract or cooperative agreement providing assurances that the State will assure maintenance for the expected life of the action.

Capping as ultimate remediation will not worsen the existing situation by enshrining in a legal agreement the non-viable situation it is designed to correct. The legal agreement utilized to memorialize any remedial action agreement with PRPs, will instead ensure that after remedial action at the site, conditions do not revert to the current conditions. After superficial remedial work at the site in 1978 and 1979, no provisions were made to ensure that the site cover was maintained and no monitoring of groundwater was included.

Comment #3

[Dr. Velma Campbell]

This commentor proposes remediation involving removal of waste for long term proper storage or destruction because:

1. The land would be restored to a useful condition for commerce, recreation delveopment or nature. Also, nearby property values would be preserved.

2. Facilities developed or converted for management of hazardous waste may be utilized in the future for other purposes. Construction, conversion and operation of these facilities would provide jobs for a wide variety of local work force.

Two examples of this type of remedial action provided by this commentor are:

1. Modify existing, underutilized storage facilites to contain the Bayou Sorrel wastes and construct new facilities for long term storage.

2. Dispose of waste and wastes by offsite incineration in facilities likely to be available in the next two years.

3. Utilize kilns licensed and operating for the processing of recoverable waste products.

EPA's Response to Comment #3

EPA, in its FS, has evaluated the offsite incineration remedy suggested by this commentor and found it to be much less cost effective and time effective than other onsite and off-site remedies. Based on an estimated volume of 1,000,000 cubic yards of waste and contaminated material at this site, it could take eighty years to complete this remedy.

The long term storage proposed by this commentor would not only drastically increase the cost of an ultimate remedy but would also increase the exposure to the environment because of the additional handling, and transportation.

EPA is not aware of the kilns licensed and operating for the processing of recoverable waste products discussed in this comment. Even if these kilns were available locally,the volume and nature of the Bayou Sorrel wastes would be prohibitive to this type of operation. First of all, there is a wide range of wastes that were mixed at the Bayou Sorrel site. These include pesticides, petroleum refinery wastes, petrochemical wastes, and other industrial wastes. It would be virtually impossible to recover portions of this mixture. Compounding the problem is the method of waste stabilization that was used when the site was originally closed in 1978-79. The wastes were at that time mixed with large quantities of soil and other stabilizing agents. The total volume of waste/contamimated soil is estimated to be 1,000,000 cubic yards.

Also, this commentor discusses the possibility of storing the Bayou Sorrel wastes to allow access to the materials for research into chemical mix behavior or so that commerical ventures may be developed to extract valuable components from the waste mixture. Again, the extensive quantity of the soil-waste mixture would prohibit these uses and because of the nature of the mixture, as discussed above, it would be virtually impossible to separate the waste components. Likewise, it is not likely that this large quantity of hazardous waste mixture would ever be used for research purposes. Even so, some form of ultimate disposal would be necessary at some point in time.

Comment #4

[Dr. Velma Campbell]

This commentor suggests that further chemical analysis of wastes and characterization of wastes for suitability of disposition is necessary.

EPA Response to Comment #4

While EPA performed limited analyses of waste during its site Remedial Investigation, sufficient information is available concerning the nature of the wastes at the Bayou Sorrel site. Extensive information concerning categories of waste and specific wastes at the Bayou Sorrel site is available in the form of site records, information provided by companies in 104(e) responses, and other documents. Also, State employees have provided EPA with invaluable information from first hand observations of site activities during actual operations and during closure operations in 1978 and 1979. State personnel were on site regularly during closure of the site and have provided information to EPA concerning locations of waste, stabilization techniques, etc. EPA does not feel that additional sampling and analyses of waste is necessary.

Comment #5

[Michael Tritico - RESTORE]

This commentor feels that the danger at the Bayou Sorrel site has not been properly documented. Specifically this commentor mentions that there are not enough monitoring wells testing enough strata and for enough chemicals to be certain that heads of plumes have been located nor to demonstrate the direction and speed of movement.

EPA Reponse to Comment #5

Since 1981, a total of 23 monitoring wells have been installed at the Bayou Sorrel site and groundwater samples analyzed. Four of these wells penetrate into the deeper plaquemine aquifer and the remainder are screened in the shallow alluvial aquifer. Results of analyses of these monitoring

wells (including recent Remedial Investigations conducted by EPA and the Bayou Sorrel Task Force) do not indicate that there is extensive migration of waste constituents from former waste disposal areas. Each sample was analyzed for the 129 inorganic and organic constituents each time. Each of these monitoring wells has been situated so that former waste disposal areas are virtually surrounded and the direction of any migration would be detected.

Comment #6

[Michael Tritico - RESTORE]

This commentor does not want delays in solving the problem because the Bayou Sorrel site is often flooded, is subject to catastrophic scouring during a leve crevasse, will be submerged year round within a hundred years, is hydraulically connected with local aquifers, and toxic materials cannot be left in situ because they will not stay in situ.

EPA Response to Comment #6

EPA also feels that expeditious remedial action at this site is appropriate. We are aware that delays have come up during investigative work at the site but prior to initiating any remedial action at a Superfund site, EPA is obligated to define the extent of the problem and select the cost effective remedy that will protect human health and the environment. Evidently, this commentor equates "solving the problem" with the total removal and disposal or treatment of the waste and related contaminated soil at the Bayou Sorrel site. EPA is aware of the problems of frequent flooding, potential of catastrophic scouring in the event of a levee crevasse and that sea level around the world is rising. Each of these considerations will be addressed individually and collectively during the design of the remedy and monitoring program at the Bayou Sorrel site.

Even though the Bayou Sorrel Site is connected with local aquifers, the characteristics of the soils at the site are such that migration of hazardous constituents from former waste disposal areas will be minimal. No contamination of the Plaquemine (deeper) aquifer has been detected; contamination is not expected because of the upper hydraulic pressure of this aquifer.

Some waste constituents have been detected in the shallow aqufer but at low levels (<100 ppb) and mostly in isolated instances (i.e. no evidence of leachate plumes. The concern that toxic materials cannot be left in place because they will not stay in place is unfounded. Results of extensive sampling (EPA, State, and PRPs) of monitoring wells, soil, surface water, and biota at the site indicate that the waste is staying in place. The long-term monitoring and maintenance that would be included in any onsite remedy would ensure that the integrity of remedial actions is maintained and enable EPA to determine the extent and direction of any contaminant migration.

Comment #7

[Michael Tritico-RESTORE]

This commentor feels that artesian pressure from below and inundative pressures from above will continue the spread of dangerous materials until those materials are removed.

EPA Response to Comment #7

The studies conducted at the Bayou Sorrel site do show that the hydraulic gradient of the lower (Plaquemine) aquifer is above land surface most of the year. However, EPA feels that this condition, instead of dispersing waste constituents, would prevent migration of these waste constituents downward to the Plaquemine aquifer. The inundative pressures from above" would be prevented from contacting the wastes and contaminated soil by means of a clay cap. The design of this cap would be such that not only would surface water be prevented from contacting the waste or contaminated soil by a clay cap and geomembrane liner, but surface water would also be prevented from contacting the cap by a layer of topsoil and a sand drainage layer above the clay cap. There will also be a drainage layer below the cap that will collect any waste leachate caused by the artesian pressures of the Plaquemine Aquifer along with pore water generated because of the weight of the cap causing settling.

Comment #8

[Michael Tritico-RESTORE]

This commentor suggests that a slurry wall does not seal from below nor above nor from the side in the case of a levee crevasse. Also, a slurry wall must be keyed into a suitable aquiclude and none exists at the site.

EPA's Response to Comment #8

EPA agrees that a slurry wall does not seal from the top nor bottom; the function of a slurry wall is to prevent lateral migration of contaminated groundwater or leachate. If a slurry wall were utilized at this site, it would be designed so that lateral migration would not occur. This would include installation of the wall below the bottoms of waste disposal areas and would cut off the more permeable lenses beneath the site. Upward migration of contaminated groundwater would be collected by the drainage system beneath the cap and would be prevented by the cap system itself.

Concerning the issue of no suitable aquiclude at the site, EPA studies have shown that the soils underlying the Bayou Sorrel site are of sufficiently low permeability to prevent significant downward migration. This, coupled with the artesian pressure of the lower aquifer, would act to preclude downward migration of contaminated groundwater, as discussed in the Response to Comment #1.

However, the RI conducted at the Bayou Sorrel site did not confirm that waste constituents are migrating from the former waste disposal areas via groundwater, and a slurry wall is not necessary around the entire site.

Comment #9

[Michael Tritico - RESTORE]

Indications from preliminary monitoring data have not been correlated with data indicating that chlorinated hydrocarbon and an alkaline influence are destructive to clay soils. This comment was evidently based on a three page letter report (attached to the commentor's letter) concerning sodium hydroxide effects and ethylene dichloride light end wastes effects on in situ clay. This comment was also made by Mr. Tritico at the February 26, 1986 public meeting.

EPA Response to Comment #9

In this commentor's oral comments at the February 26 public meeting he mentioned that at the Bayou Sorrel site there are pH's approaching 10 and chlorinated hydrocarbon reported in large quantities.

EPA is not aware of any chlorinated hydrocarbons being reported in large quantities during the RI at this site, nor in other studies conducted by the LDEQ and the PRPs. Concentration of chlorinated hydrocarbons were generally less than one part per million (ppm). The report submitted by Mr. Tritico was a laboratory test conducted for a specific site using soil from that site. The test was conducted using ethylene dichloride (EDC) light end wastes; the report does not give the concentration of EDC, but it is assumed that it would approach 100%. Since concentrations of chlorinated hydrocarbons at the Bayou Sorrel site are <1 ppm, comparison of the characteristics at Bayou Sorrel to results of this report would not be appropriate.

The report submitted by Mr. Tritico also dealt with laboratory tests of effects of sodium hydroxide (Na OH) on in situ clay permeability. This report discusses that the clays from the test site were destroyed by saturating with a 50% Na OH solution; this saturation raised the pH of the test soil to 13 before destruction of the clay occurred.

The highest pH measured at the Bayou Sorrel site during studies conducted by EPA, LDEQ and PRPs appears to be 9.5 (this was of waste in disposal ponds prior to the 1978-79 closure of the site) except for two isolated monitoring well samples by PRPs in 1984.

Since the report included with Mr. Trictico's letter is based on a "worst case" situation concerning pH and chlorinated hydrocarbons, it is impossible to infer the effect that the low chlorinated hydrocarbon concentrations and much lower pHs that exist at the site may have on in situ clays. In any event, the monitoring program at the site will allow EPA to constantly evaluate the migration of contaminants from the former waste disposal areas.

Comment #10

[Michael Tritico - RESTORE]

This commentor suggests that "a thoroughly inadequate amount of attention has been given to the "removal alternative". Mr. Tritico suggests that the wastes be transported by barge to GSU's Riverbend Nuclear Station at Starhill, Louisiana. There, the commentor proposes, the waste could be processed using the plasma torch technology, with small volumes of ash and salt remaining. If the plasma torch method does not fully degrade the contaminated material, the commentor recommends that other techniques could be applied such as radio frequency heating, high temperature fluid wall reactor, infrared incinerator, supercritical water oxidation, molten salt or molten glass technologies set up alongside each other and operated as a flexible system.

EPA Response to Comment #10

In evaluating alternatives for the Bayou Sorrel site, EPA retained two "removal" alternatives for detailed evaluation. These alternatives (off-site disposal at a RCRA facility and onsite incineration) are discussed in detail in the Feasibility Study developed by EPA. Transportation alternatives for the offsite disposal included barge transport as Mr. Tritico mentioned. The waste treatment alternatives proposed by Mr. Tritico were not evaluated by EPA, however, because these alternatives are not proven technologies. The National Contingency Plan (40 CFR 300.68(h)(2)(i)) requires that EPA place "... emphasis on use of established technology" in its detailed analysis of alternatives.

Also, Mr. Tritico mentions that volumes of ash and salt remaining will be minimal. Because of the physical state of wastes remaining at the Bayou Sorrel site, this is not a valid statement. When the site was closed in 1978-79, wastes remaining at the site were stabilized using soil and other addatives such as kiln dust and portland cement. Volume reduction by incineration or other thermal treatment would be, at best, minimal and volume could possibly increase due to fluffing of the treated material during the treatment process.

Comment #11

Police Jury [illegible]berville Parish; Walter Allen - Concerned citizens of Bayou Sorrel

These commentors ask the question "Who are the members of the Bayou Sorrel Task Force?"

EPA Response to Comment #11

As EPA discussed at the February 26, 1986 public meeting, the Bayou Sorrel Task Force (BSTF) is composed of a group of Potentially Responsible Parties who voluntarily banded together to negotiate with EPA concerning remedial activities at the Bayou Sorrel site. The BSTF, independent of EPA, has conducted its own RI/FS at the site and has expressed a willingness to implement their recommended alternatives (a clay cap remedy similar to EPA's clay cap alternative).

Comment #12

Iberville Parish Police Jury, Walter Allen - Concerned Citizens of Bayou Sorrel, Andrea Allen.

These commentors asked "Who determines what is cost effective?"

EPA Response to Comment #12

The National Continagency Plan requires that in selecting a remedial alternative for a site, the decision maker (in the case of Bayou Sorrel, the Regional Administrator) among other things, to take into consideration the cost of implementing the remedial actions including operation and maintenance costs. An alternative that far exceeds the costs of other alternatives and does not provide substantially greater protection of public health or the environment should be excluded. The NCP requires that the Agency select the cost effective alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment considering cost, technology and reliability of the remedy. The Regional Administrator will make this decision based on information provided in the RI/FS and other information provided by EPA staff and consultants.

Comment #13

Iberville Parish Police Jury, Walter Allen - Concerned Citizens of Bayou Sorrel, Andrea Allen, Leslie Ann Kirkland

The above commentors asked the question "Will local people have any input into the remedial alternative selection?"

EPA Response to Comment #13

As discussed at the public meeting, the purpose of the public comment period and public meeting is to receive comments on the Feasibility Study. The review and comment period precedes selection of the remedial response and the summary of public comments is one of the documents utilized by the decision maker in selecting the appropriate remedy for any particular site.

Comment #14

[Concerned Citizens of Bayou Sorrel, Iberville Parish Police Jury]

These commentors requested an extension of time for submission of comments on the Feasbility Study.

EPA Response to Comment #14

EPA agreed at the February 26 Public meeting to extend the public comment period from March 5 to March 15, 1986.

Comment #15

[Dale Bouquet - Iberville Parish Police Jury, Walter Allen - Concerned Citizens of Bayou Sorrel]

These commentors requested that EPA provide financial aid to Iberville parish so that the parish attorney and Parish engineer can be involved in investigations at the Bayou Sorrel site. Also, these commentors requested that EPA provide money to assist in a Parish investigation of soil and water (at the site).

EPA Response to Comment #15

Section 104 of the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) provides that where it is determined that a State or political subdivision of a State has the capacity to carry out any or all of the actions authorized under Section 104 of CERCLA, EPA may enter into a Contract or Cooperative Agreement with that entity to take those actions using fund monies. In the fall of 1982, the Louisiana Department of Natural Resources (now Department of Environmental Quality) requested that EPA enter into such a Cooperative Agreement for the RI/FS at the Bayou Sorrel site. EPA allocated money for the State to conduct these studies contingent upon no responsible parties being willing to undertake remedial activities at the site. No responsible party was willing to voluntarily undertake remedial activities. However, the State subsequently withdrew its application for a Cooperative Agreement and EPA proceeded with the RI/FS.

These commentors are requesting fund monies so that the parish can be involved in the investigation at the Bayou Sorrel site and also conduct its own studies. EPA feels that the studies authorized by Section 104 of CERCLA have been completed and at this point no further investigation is needed. The next step in the remedial process, as outlined in the NCP, is Remedial Design. EPA plans to negotiate with the Bayou Sorrel PRPs for the Remedial Design and also the following phase, Remedial Action (construction). All these actions, if implemented by the PRPs, will be directly overseen by EPA and its representatives.

Comment #16

[Iberville Parish Police Jury, Walter Allen President - Concerned Citizens of Bayou Sorrel]

This comment questions whether the remedial alternatives described in the FS apply to only the former waste disposal areas or whether they also apply to any areas where wastes have migrated from the waste disposal areas.

EPA Response to Comment #16

As explained in the FS, there are some isolated areas where surface contamination has been documented. These areas are in the vicinities of former waste disposal areas and may be due to either seepage or spillage during 78-79 closure activities. These areas will all be included in the ultimate remedy for the Bayou Sorrel site. For the geomembrane cap alternative this contaminated soil would be placed under the cap above the former waste disposal areas.

Comment #17

[Iberville Parish Police Jury, Walter Allen, PRESIDENT - Concerned Citizens of Bayou Sorrel, Andrea Allen]

These commentors questioned how long the waste at Bayou Sorrel will remain toxic.

EPA Response to Comment #17

With the geomembrane cap remedy, the wastes and contaminated soil would be protected from natural destruction mechanisms such as oxidation, sunlight, aerobic microorganisms, and other elements. Even though there will be some degradation of those wastes it will be minimal; therefore, the wastes, for all practical purposes, would remain toxic forever.

Comment #18

(Iberville Parish Police Jury, Walter Allen, President - Concerned Citizens of Bayou Sorrel]

These commentors are concerned with what chemicals are on site and what impact will leaving those chemicals on site have on the area.

EPA Response to Comment #18

As discussed in the FS, the wastes disposed of at the Bayou Sorrel site generally fall into one of the following three categories:

1. Process wastes from pesticide/herbicide manufacturing including distillation residues, contaminated packaging, and miscellaneous wastes.

2. Sulfide-containing wastes (scrubber blowdown and spent caustic) from hydrocarbon processing and exploration activity.

3. Spent wash solutions from boiler-cleaning and process equipment-cleaning contractors.

Soil sampling results indicate that the former ponds contain an assortment of organic compounds, including herbicides and pesticides. During its investigation of the site EPA has developed an extensive list of compounds that may have been disposed of at the Bayou Sorrel site. Since many of these compounds may not be hazardous wastes or hazardous substances and since these compounds may decompose with time into other compounds, EPA analyzed all samples for the full list of 129 priority pollutants.

As discussed in previous comments, leaving these wastes in place should not adversely affect the areas. EPA will require long term monitoring and maintenance to ensure that hazardous substances are not leaving the site.

Comment #19

[Iberville Parish Police Jury; Walter Allen, President - Concerned Citizens of Bayou Sorrel]

Several commentors were concerned with various aspects of access/development restrictions such as: will development on and around the site be limited; how will people be kept off site; will site be safe to hunt and fish after remediation; etc.?

EPA Response to Comment #19

Each of the onsite alternatives has the same security features as part of the long term monitoring and maintenance activities. These include a six foot high chain-link fence around the capped areas, gravel access roads around the fenced areas to encourage persons on the site to go around rather than over capped areas, and signs warning of the waste disposal areas. Inspection and repair of these security features will be an integral part of the operation and maintenance of this site.

Comment #20

[Iberville Parish Police Jury, Walter Allen, Concerned Citizens of Bayou Sorrel, Mr. Bouquet]

This group of commentors is concerned with liability for this site once the Remedial Action is completed. Specific questions asked include: what happens if contaminantion occurs after cleanup? Are the Iberville Parish Police Jury and State responsible? Will money be available for future testing of soil, groundwater, etc.? If so, for how long and how much per year?

EPA Response to Comment #20

As we discussed at the public meeting, EPA plans to negotiate with PRPs for voluntary implementation of the remedy at the Bayou Sorrel site. If these negotiations are successful, EPA will require that the PRPs conduct long term monitoring and maintenance at the site. If the wastes remain at the site, the PRPs would retain liability for problems that develop in the future at this site; this future liability is included in the Consent Decree.

If Federal funds were to implement Remedial Action at this site, the State would have to provide all future maintenance of the remedial action for tne expected life of the remedy. This would not mean that the State would assume liability for the site, but would assume responsibility for maintenance.

Future testing of media at the site will be the responsibility of the PRPs pursuant to the Consent Decree. EPA of course, would oversee this sampling, including analysis of a limited number of samples for verification of accuracy of PRP analyses. It is impossible, however, to determine how much money per year will be available and for how long it will be available.

Comment #21

[Mrs. Oswald P. Templet, Mr. John J. Battieste]

These commentors own property and/or have water supply wells in the area of Bayou Sorrel and are concerned that wastes may have migrated off-site.

EPA Response to Comment #21

In conducting the Remedial Investigation, two of the main concerns at the Bayou Sorrel site were that waste constituents might leave the former disposal pit via ground water or surface water. Both of these pathways of migration have been sampled extensively by EPA, LDEQ and PRPs and no offsite migration of contamination has been detected. Also, as discussed in previous responses, both these pathways of migration will continue to be monitored as part of the long term operation and maintenance after completion of the remedy.

Comment #22

[Mr. Roy Zito, Mr. Darrel Stevens - Citizen Activists Against Pollution]

These commentors were concerned that organisms living at the site might be contaminated or become contaminated in the future.

EPA Response to Comment #22

Organic analysis was performed on tissue samples of catfish, bream, crayfish tail meat, and crayfish green gland, all collected onsite. Fish samples were collected from the borrow lake and small onsite pond, and crayfish from numerous shallow standing water areas onsite. No organic compounds of non-biological origin were found in any sample, and inorganic results were typical for uncontaminated tissue. Continued monitoring of organisms onsite will be included as part of the long term operation and maintenance of the remedy.

Comment #23

[Walter Allen, President - Concerned Citizens of Bayou Sorrel, Andrea Allen]

These commentors had specific questions concerning site conditions and certain aspects of the remedial alternatives. These questions included: What is a slurry wall? How deep is the proposed slurry wall? How deep were wood fragments found at the site? Will wood fragments cause a conduit through the soil when the wood decomposes.

EPA Response to Comment #23

The slurry wall proposed for the Bayou Sorrel site is of the soil bentonite type. In this type of slurry wall, a trench (approximately 3 ft. wide) is excavated around the waste disposal areas to a specified depth.

The spoils from this trench are then mixed with bentonite (a form of clay) and pushed or pumped back into the trench. The clay absorbs water and swells resulting in a low permeability underground containment wall around the waste disposal areas. The purpose of the slurry wall is to prevent groundwater from migrating into or out of the waste disposed areas. The depth of the slurry walls at the Bayou Sorrel site would vary according to depth of waste, areas of higher permeability etc., but would generally be 30-40 feet deep.

Concerning the depth of wood fragments at the site, soil borings were done across the entire site, some to a depth of 80 feet. Indications are that 25 or 30 feet was the deepest locations where wood fragments were found. There is no indication that wood fragments at this site would form major conduits for migration of contaminated ground water, since in place permeability tests at this site included many of the bore holes where wood fragments were found.

Comment #24

[Robert Mooney - Plaquemine City Coucil]

This commentor was concerned with two aspects of groundwater migration at the Bayou Sorrel Site:

1. Laboratory determination vs field determination of soil permeability and,

2. Hydraulic balance at or near the site may change.

EPA Response to Comment #24

EPA agrees with this commentor that there may be differences in permeability determined in this field vs Laboratory. However, based on data collected by EPA and others concerning permeability at the site, EPA feels that there is low potential for groundwater migration at the site. In studies done at this site, both methods of determining permeability have been used for comparison. The reason for this is there are arguments that each method may be more accurate than the other. Utilizing all available permeability data and the fact that no significant contaminant migration in groundwater has been detected, EPA feels that soils at this site are of sufficient impermeability to prevent contaminant migration in groundwater.

EPA also agrees that the Hydraulic Balance may change at the site. This is one of the items that will be monitored at this site and if data indicate that additional corrective actions may be necessary in the future, EPA could then ensure the implementation of that action.

Comment #25

[Jesse Wilson - Iberville Parish Police Jury, Andrea Allen]

These commentors asked what would constitute a true emergency at the Bayou Sorrel site and whether EPA has a funding mechanism to handle emergencies.

EPA Response to Comment #25

In determining the appropriate extent of action to be taken at a given site, EPA reviews all site data to determine if a Remedial Action is appropriate. If it is determined that there is an immediate risk to public health or welfare or the environment, the EPA may take action to control the threat. Criteria used to evaluate a site for a removal action include:

1. Contamination of drinking water supplies;
2. Hazardous substance, etc. stored in bulk container;
3. Threat of fire or explosion;
4. High levels of hazardous substances, etc. in soils at or near the surface that may migrate;
5. Exposure to hazardous substances, etc. by nearby populations, animals or food chains.

The removal action may be conducted either by utilizing Superfund money, or whenever possible, by the Responsible Parties.

Comment #26

[Mr. Milton Vaughn]

This commentor is concerned with the effect that buried containers which might rupture would have on releasing contaminants to the groundwater.

EPA Response to Comment #26

One area of the Bayou Sorrel site was utilized specifically for drum disposal. Through our extensive field investigations and record reviews (including information provided by LDEQ), we have determined that most containers disposed of at the site were emptied and crushed prior to disposal. Another area of the site was rumored to have received filled drums but investigation (magnetometer survey) failed to confirm the presence of drums in that area.

Comment #27

[Mr. Milton Vaughn, Mr. Rod Ritterman, Mr. Walter Allen]

These commentors expressed concerns with monitoring wells and oil wells at the site. One of these commentors wanted to know what keeps contamination from following the well bore and contaminanting, the (Plaquemine) aquifer. Another wanted to know if the integrity of monitoring wells onsite is checked as an injection well is checked. The third concern deals with the effect that an existing oil well on the site would have on waste migration.

EPA Response to Comment #27

In any field investigation at a hazardous waste site where soil borings of any type are conducted, every precaution is taken not to contaminate any areas because of improper constructions of the boring (or well). EPA and contractors in the hazardous waste field typically utilize some form of sealer between the borehole and well casing. This sealer is normally a cement-bentonite mixture placed in the void from above the screening material to the ground surface. In the case of bore holes that are not cased as monitoring wells, the bore holes are usually grouted to the surface with the same mixture. This grout mixture will prevent contamination from migrating downward along the bore hole.

EPA does not test the integrity of its monitoring wells as is done with injection wells. Injection wells are normally operated under very high pressure, with liquids being forced into the ground by this high pressure, whereas monitoring wells are for the purpose of removing ground water from the ground, usually by means of a bailer or some form of pump and would not stress this well casing. However, visual inspections will be made of monitoring wells as part of the overall monitoring plan and data will be continually evaluated which in itself could indicate problems with specific wells.

The oil well found on site is located in the borrow lake away from contaminated areas and should not be affected by waste from the site. In any event, the well has been abandoned and is no longer in use.

Comment #28

[Mr. Milton Vaughn, Mr. Wilson, Andrea Allen, Robert Mooney, Darrel Stevens]

These commentors had several comments dealing with the problems of installing a clay cap in southern Louisiana, one being that the clays in the area are "fat" clays which upon drying out will shrink and crack. Another is that the area where the site is located is subject to frequent flooding and water would come up underneath the cap.

EPA Response to Comment #28

Any cap installed at the Bayou Sorrel site will be designed to alleviate the problems mentioned by the above commentors. Any clay soil has a tendency to shrink and swell in relation to the moisture content of the soil. This problem will be addressed in two ways at the Bayou Sorrel site. First, the cap is designed so that it is protected by sufficient topsoil and vegetation to prevent dessication of the clay. Secondly, the long term monitoring and maintenance will provide for periodic visual inspections of the capped areas so that potential problem areas could be detected. Also, the geomembrane layer over the clay will assist in preventing dessication and will provide an extra impermeable layer in the event the clay cap does fail.

The cap itself will be designed so that any flood waters encroaching on the site would not pond on capped areas. The cap will be keyed a few feet into the native clays at the site so that flood waters cannot enter under the cap. In the event any surface waters were able to contact wastes, any contaminated water would be collected by the drainage layer installed directly over the waste.

Comment #29

[Nolan Henson, Mr. Bouquet]

These commentors were concerned that the proximity of the Bayou Sorrel site to the Atchafalaya River Flood Protection levee might cause problems either because the levee might be moved closer to the site or there could be a catastrophic levee failure near the site.

EPA Response to Comment #29

EPA is not aware that the Corps of Engineers is planning to move the levee closer to the Bayou Sorrel Site. If this were to happen and if it did affect the Bayou Sorrel site, there would be a gradual change and any problems would be detected through the long term monitoring and maintenance program.

Concerning the catastrophic failure of the levee, this problem will have to be taken into consideration during the design phase of the remedy. The cap could be designed to withstand this sort of catastrophic failure if it were to happen.

Comment #30

The majority of commentors at the public meeting and those submitting written comments favored the removal alternatives at the Bayou Sorrel site. This would involve excavation of the wastes and contaminated soil for transportation to a secure, RCRA compliant landfill.

EPA Response to Comment #30

Although this Remedial Alternative would be an effective, reliable method of site remediation, there would still be major problems and efforts associated with this remedy. This alternative would increase the short term risk to site workers, the environment, and public health since waste would be excavated and exposed prior to transportation to an offsite disposal area. Also, there would be an increased risk from traffic accidents due to the number of truckloads of waste that would be hauled from the site.

Also, cost would be an important consideration with this remedy. Because of the enormous volume of material to be excavated, transported and disposed of the cost for this remedy would be over $500 million. Since this extensive a remedy is not necessary at the Bayou Sorrel site to protect human health and the environment, this would not be the most cost effective remedy.

Comment #31

Several commentors were concerned with the injection well and associated pits located near the Town of Bayou Sorrel approximately 6 miles from the site. Most wanted an investigation and monitoring of this facility, including cleanup of the abandonded pits located at the well.

EPA Response to Comment #31

The injection well at Bayou Sorrel is an active facility that is currently regulated pursuant to the Resource Conservation and Recovery Act (RCRA) and the Safe Drinking Water Act.

Current regulations require that prior to issuance of a RCRA permit, any former disposal areas at a facility must be addressed. Also prior to issuance of a RCRA permit, a public meeting must be conducted to receive input from the public.

Comment #32

[Bayou Sorrel Task Force]

On-site incineration and off-site landfill disposal are inappropriate remedial technologies for the site. They place the population in needless risk of traffic injury and exposure to wastes, overwhelm limited landfill capacity and do not provide incremental benefits to balance these negative effects.

EPA Response to Comment #32

EPA agrees that On-site incineration and off-site landfill disposal are not the most cost effective alternatives which protect human health and the environment. EPA is no longer considering these two remedies.

Comment #33

[Bayou Sorrell Task Force]

There is no demonstrated groundwater contamination at the site at the present time which requires slurry wall construction. The risks of slurry wall construction are considerable, the costs of wall construction are unpredictable, and the effectiveness of a completed slurry wall is not assured.

EPA Response to Comment #33

Even though extensive contamination of groundwater at the Bayou Sorrel site has not been demonstrated, organic analytical results indicate the possibility of organic contamination of shallow groundwater. This contamination is at low levels and does not appear to be widespread.

Based on this data and the fact that the soils in the vicinity of the site are relatively impermeable, EPA feels that a slurry wall around the entire site is not necessary at this time. However, a mechanism would be included in the consent document to require implementation of additional remediation should contamination be detected in groundwater through the monitoring program. This will be included as part of the overall monitoring. Data generated through this program can be evaluated after a period of years to determine if additional remediation is necessary.

Comment #34

[Bayou Sorrel Task Force]

The caps designed for capping alternatives are too massive for site conditions. They contain two unnecessary sand layers and are too great in areal extent. Unnecessary and extensive settlement will occur from the weight of the installation if the EPA cap design is implemented.

EPA Response to Comment #34

EPA is aware of the soil conditions at the site and the problems with settling at the site. These problems can be overcome through design of the cap, with features such as preloading for settlement prior to beginning actual cap construction. This cap design is necessary to prevent surface water from contacting wastes and contaminated soil along with prevention of direct contact with waste by people or wildlife. The two sand layers are included in the cap design as drainage layers. The sand layer immediately above the waste can be modified to include less sand and an additional geofabric layer for pore water drainage. The first is to be located directly above waste and below the cap. This layer would intercept pore water squeezed out of the soil by cap settlement and allow it to be collected for disposal. The second sand layer is to be placed above the clay cap and geomembrane and below the top soil layer. This sand layer would prevent surface water from reaching the cap.

Comment #35

[Bayou Sorrel Task Force]

The caps designed for the cost evaluation of capping alternatives contain needless costly design elements, i.e., a surface water run-off collection pond, security during construction, an on-site laboratory, a below grade barrier to burrowing animals and a passive gas vent system which are not protective of human health and the environment.

EPA Response to Comment #35

While the features mentioned above may be replaced by other means of control, the functions they are designed to address are necessary. For example, if people are protected from direct contact with hazardous substances or other dangers during construction, a security guard may not be necessary. Each of these elements that the Bayou Sorrel Task Force feels are "needless" can be addressed during the Remedial Design phase prior to implementation of the remedy.

Comment #36

[Bayou Sorrel Task Force]

The cost of a geomembrane is stated as being insignificant to the total cost of a cap. Inclusion of a geomembrane escalates remediation costs an additional $1.2 million and provides only a minimal addition level of assurance against infiltration compared to the clay cap alternative.

EPA Response to Comment #36

Generally, the geomembrane cap alternative meets the current RCRA guidance and this alternative represents in-place closure in accordance with current RCRA regulations and guidance. This geomembrane layer would effectively isolate the contamination from direct contact and, in addition, add an extra layer of impermeability to effectively control infiltration and waste seepage. In addition, this geomembrane would add an extra measure of protection if the clay cap failed due to differential settling or other problems.

Comment #37

[Bayou Sorrel Task Force]

Post-closure ground water monitoring is proposed to be semi-annual for 30 years. Semi-annual monitoring in early years is appropriate because of the possibility of altering ground water velocities during and immediately following construction. In later years when ground water velocities return to their very slow rates, semi-annual monitoring is not appropriate.

EPA Response to Comment #37

As the above commentor states the post-closure monitoring period is for a minimum period of thirty years. Even though the FS calls for semi-annual monitoring, this frequency could be reduced, depending on data collected during the monitoring program.

Comment #38

[Bayou Sorrel Task Force]

The Task Force does not agree with much of the EPA cost estimating assumptions and methodology. However, for comparison purposes only, properly using that methodology on the BSTF cap design results in a capital cost estimate that is 8% less than the lowest cost EPA capping alternative. This lower figure is based on (A) not changing the BSTF 190 mil geofabric to a composite geofabric/geo-net/geofabric and (B) not using an erosion control mat on the gently sloped 4% edges of the BSTF cap. The clay cap remedial alternative designed and configured in the Bayou Sorrel Task Force Feasibility Study remains a remedial alternative that effectively mitigates threat to, and provided adequate protection of, public health and welfare and the environment.

ATTACHMENT D: STATEMENT OF WORK

APPENDIX A

Proposed Geotechnical Boring Program For Slurry Wall Design, Cap Settlement Analyses and Hydrogeological Confirmation

APPENDIX A

PROPOSED GEOTECHNICAL BORING AND TESTING PROGRAM FOR SLURRY WALL DESIGN, CAP SETTLEMENT ANALYSES AND HYDROGEOLOGICAL CONFIRMATION

BAYOU SORREL REMEDIATION DESIGN

Objectives

The objective of the proposed boring program for slurry wall and cap design is to obtain geotechnical data on subsurface soil conditions necessary to perform the following design analyses:

- Refine the horizontal and vertical alignment of the proposed slurry walls.
- Determine slurry trench factor of safety against slope failure due to cap fill.
- Predict the effect of cap fill on vertical and horizontal strain of slurry trenches.
- Determine optimum soil/bentonite mix design and permeability.
- Predict short-term and long-term settlement of the proposed remediation caps for the South and North Areas and porewater production rates and volumes.

Additional cone penetrometer borings described below will be performed in the South Area to provide confirmation of hydrogeological conditions predicted from previous site borings. This confirmation will be used to determine the location of site post-construction ground water monitoring wells in that area.

Scope

Figures A-1 and A-2 indicate the location and purpose of each proposed boring in the South and North Areas, respectively. Slurry wall borings will be spaced on 100 ft. centers in the South Area and 200 ft. centers in the North Area. Outside the location of the proposed slurry wall, borings for cap settlement data will be spaced around the remaining South Area perimeter. Hydrogeological confirmation borings using a cone penetrometer will be spaced on 50 ft. centers except where previous borings or monitoring wells already provide the necessary subsurface data. Depth of these cone penetrometer borings will be 40 feet.

Table A-1 lists the proposed depth of each geotechnical boring, sample frequency and schedule of analyses to be performed on each boring sample. Table A-2 provides cumulative totals for all borings and analyses under the proposed scope of work. A listing of test methods to be used (ASTM or Corp of Engineers) for analyses is provided in Table A-3. In addition, a soil/bentonite mix design analysis outlined in Table A-4 will be performed to identify the blend ratios of bentonite, proposed excavated material, and imported soil (sand) for desired permeability and structural characteristics.

As part of this work scope, suitable sources of sand for slurry wall construction will be located in the Bayou Sorrel area. Samples taken during this investigation will be used in the slurry wall mix design analyses (Table A-4).

Drilling and Sampling Procedures

Geotechnical Borings

Subject to access, above/below ground obstructions, and site specific stratigraphy, all geotechnical borings will be advanced by dry drilling with hollow stem augers. Field extruded Shelby tube or split spoon samples will be used for borehole logging and for disturbed sample analyses (see Table A-1). Each sample will be extruded from the Shelby tube onto clean PVC trays. The ERM-Southwest hydrogeologist will log the core sections for each boring and select the appropriate samples for physical testing. These samples will be wrapped tightly in aluminum foil, then bagged in heavy duty plastic-type bags and placed in boxes for shipment or storage.

For those analyses requiring an undisturbed sample (see Table A-1), the unextruded Shelby tube will be sealed at both ends in the field with wax to assure minimal moisture loss of the sample. The undisturbed Shelby tube samples will then be placed in core boxes for shipment or storage after a thorough visual inspection of the wax seals integrity.

Samples (disturbed and undisturbed) will be selected for physical analyses after in-house review of the borehole logs.

All geotechnical borings will be logged in the field by the ERM-Southwest hydrogeologist who will supervise sample collection, perform hand penetrometer tests, make note of soil strata, soil/water conditions, color and textural changes and other pertinent information as drilling proceeds.

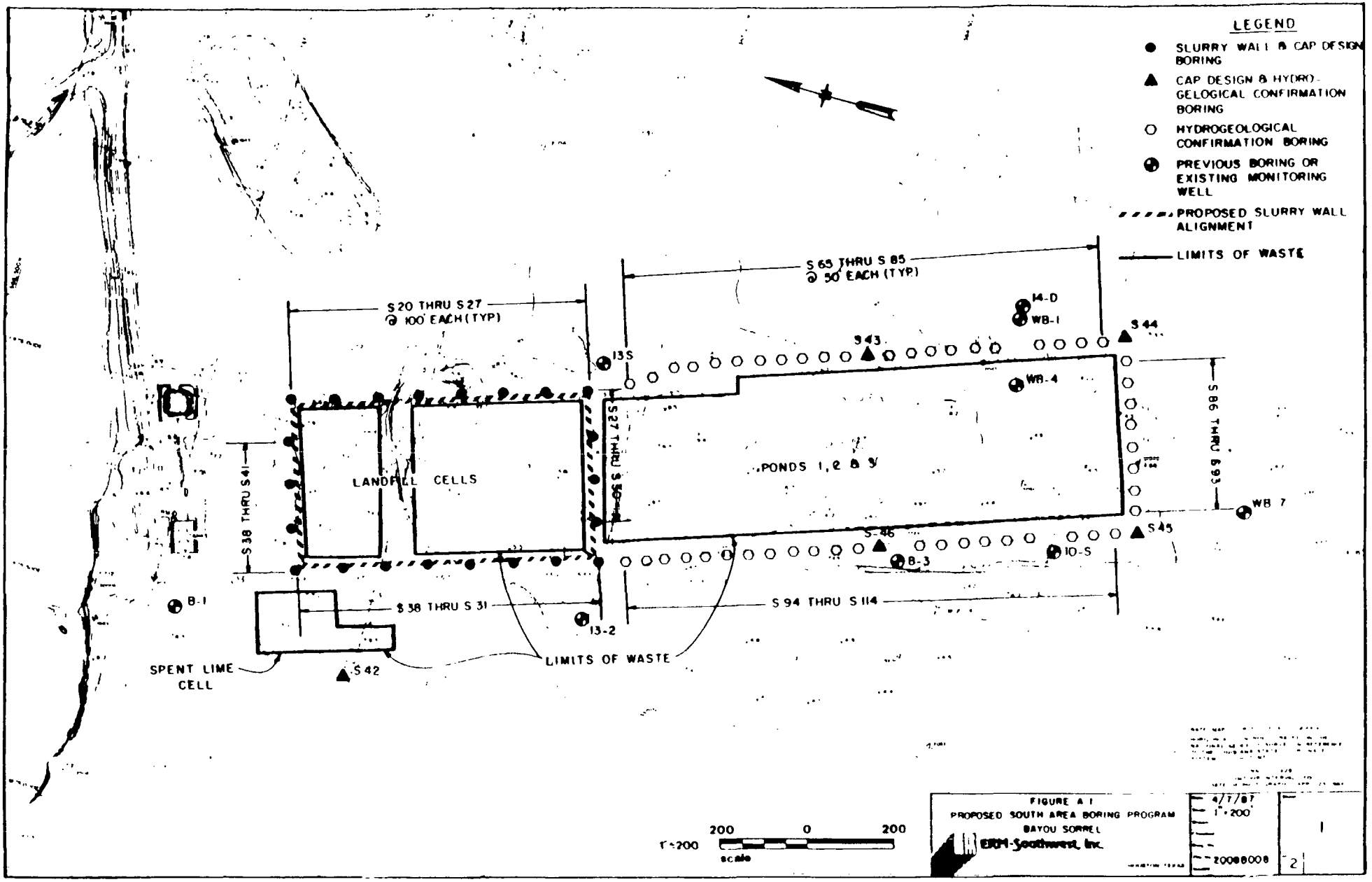
Borings made along the proposed slurry wall alignments will be tremie grouted with bentonite only to prevent possible cement interference with the soil/bentonite slurry that will be made from the alignment excavation. All other borings will be tremie grouted using an 8:1 cement/bentonite (by weight) grout. Decontamination of the drill rig equipment between borings will not be performed unless affected soil is encountered during the previous boring (visual and HNU reading determination).

Hydrogeological Borings

All hydrogeological confirmation borings in the South Area (See Figure A-1) will be drilled by Fugro International, Inc. with a specially designed all-terrain cone penetrometer testing (CPT) drilling rig. The CPT drilling rig collects subsurface geologic information by hydraulically pushing the penetrometer, a cone shaped instrument, into the soil at a constant rate of 2 cm/sec. A continuous measurement of cone tip resistance and side friction due to the soil matrix is collected by strain-gauge load cells located inside the penetrometer. Conductivity measurements of the soil matrix are also obtained by two electrodes centrally located in the cone body. This information collected from the strain-gauge load cells and conductivity probes are directly recorded on a strip chart and simultaneously recorded in digitized form on magnetic tape.

The cone penetrometer field data will be collected and processed by Fugro International, Inc. The cone penetrometer boring results will provide information on the stratification of the subsoil, relative soil classifications, and undrained shear strength of the soil matrix penetrated.

Decontamination of the drill rig equipment between borings will not be performed unless affected soil is encountered during the previous boring (visual, HNU and H_2S reading determination). All cone penetrometer drill holes will be tremie-grouted using an 8:1 cement/bentonite (by weight) grout.


LEGEND
SLURRY WALL & CAP DESIGN BORING
CAP DESIGN & HYDRO-GELOGICAL CONFIRMATION BORING
HYDROGEOLOGICAL CONFIRMATION BORING
PREVIOUS BORING OR EXISTING MONITORING WELL
PROPOSED SLURRY WALL ALIGNMENT
LIMITS OF WASTE
S 65 THRU S 85 @ 50' EACH (TYP)
S 20 THRU S 27 @ 100' EACH (TYP)
14-D
WB-1
S 44
S 43
13S
WB-4
S 86 THRU S 93
WB 7
S 27 THRU S 36
PONDS 1, 2 & 3
LANDFILL CELLS
S 38 THRU S 41
S-46
S 45
B-3
10-S
B-1
S 38 THRU S 31
S 94 THRU S 114
13-2
SPENT LIME CELL
S 42
LIMITS OF WASTE
1"=200'
200 0 200
scale
FIGURE A 1
PROPOSED SOUTH AREA BORING PROGRAM
BAYOU SORREL
ERM-Southwest, Inc.
4/7/87
1"=200'
20080008
2

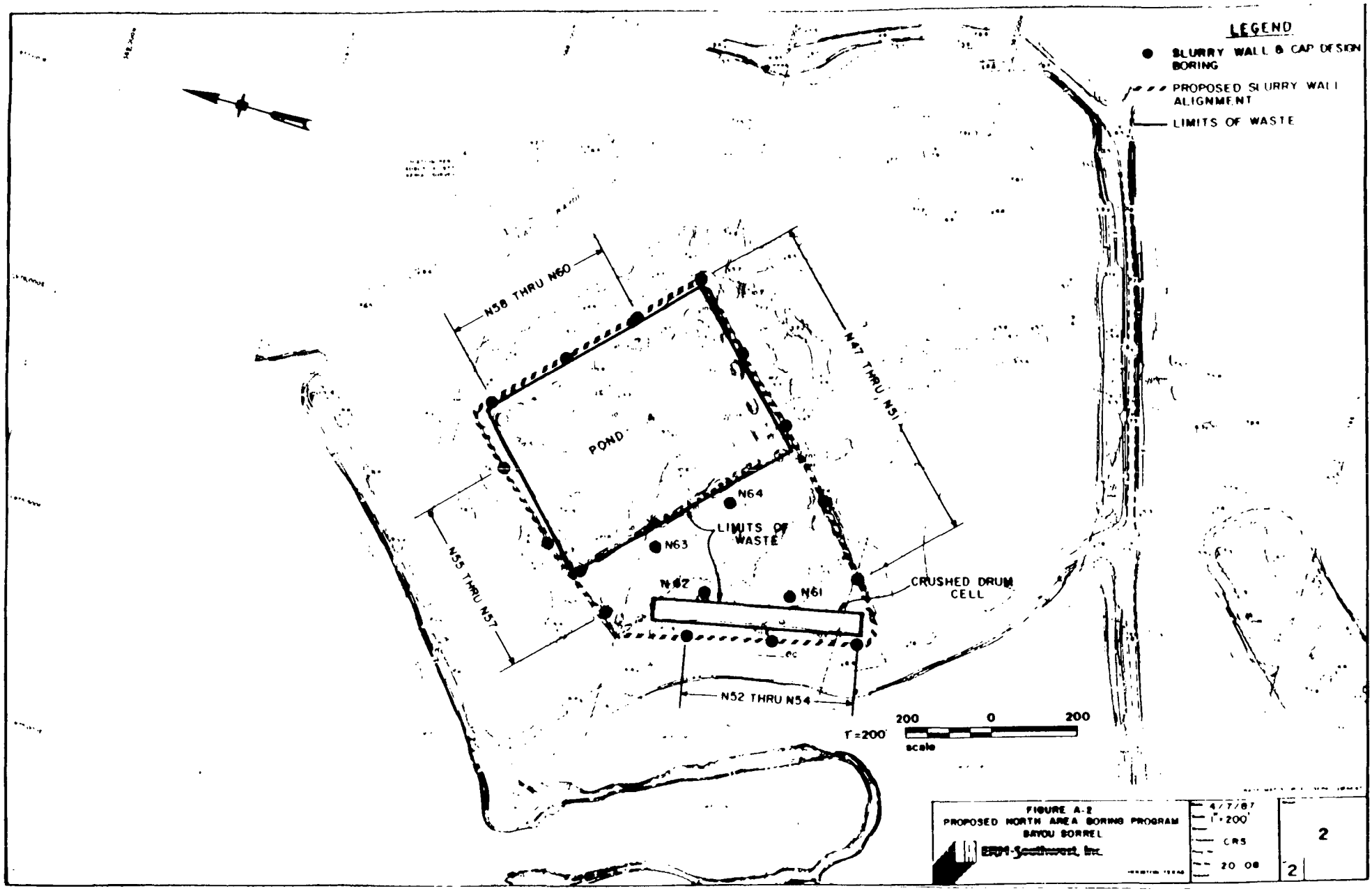

LEGEND
SLURRY WALL & CAP DESIGN BORING
PROPOSED SLURRY WALL ALIGNMENT
LIMITS OF WASTE
N58 THRU N60
N47 THRU N51
POND
N64
LIMITS OF WASTE
N63
N62
N61
CRUSHED DRUM CELL
N55 THRU N57
N52 THRU N54
200 0 200
1"=200'
scale
FIGURE A-2
PROPOSED NORTH AREA BORING PROGRAM
BAYOU BORREL
ERM-Southwest, Inc.
4/7/87
1"=200'
CRS
20 08
2
2

Table A-1

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Proposed Borings and Physical Soil Tests
South Area

Bayou Sorrel Remediation Design

				Analyses Per Boring, Insitu or Disturbed Samples (c)						Analyses Per Boring, Undisturbed Samples (d)						
Boring No.	Purpose(a)	Total Boring Depth (ft)	Total No. of Samples(b)	ASTM D2487/ D2488 Soil Class.	Moisture Content	Atterburg Limits	ASTM D2573 Vane Shear (e),(k)	Specific Gravity (f),(k)	Particle Size Distribution (g),(k)	Hand Penetrometer (h)	Unconfined Compressive Strength	Dry Density (l)	Torvane Shear tests (i),(k)	Tri-axial Compressive Strength (k)	Lab Permeability (k)	Consolidation Test (j),(k)
S20	SW,CS	60	12	12	12	2	12 tests in selected South Area borings	3 tests on selected South Area boring samples	10 tests on selected South Area boring samples	6	4	2	8 tests on selected South Area boring samples	6 tests on selected South Area boring samples	10 tests on selected South Area boring samples	4 tests on selected South Area boring samples
S21	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S22	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S23	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S24	SW,CS	80	16	16	16	2	::	::	::	6	4	2	::	::	::	::
S25	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S26	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S27	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S28	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S29	SW,CS	80	16	16	16	2	::	::	::	6	4	2	::	::	::	::
S30	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S31	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S32	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S33	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::

(a) SW = Slurry Wall Design; CS = Cap Settlement Analyses; GH = Hydrogeological Confirmation .
(b) Samples taken every 5 feet of boring depth.
(c) Field extruded Shelby Tube or Split Spoon Sample.
(d) Sealed Shelby Tube shipped to lab.
(e) 4 tests each in 3 selected South Area borings.
(f) Specific gravity (soil particles) on 1 medium stiff and 2 soft clay samples.
(g) Particle size distribution on 2 medium stiff and 2 soft clay samples.
(h) Field test performed on Shelby Tube sample before extrusion or sealing for undisturbed sample.
(i) Torvane shear on 3 medium stiff and 5 soft clay samples. Remolded Torvane shear on same samples.
(j) Consolidation Test on 1 medium stiff clay and 3 soft clay samples.
(k) These samples will also be analyzed for soil classification, moisture content, Atterburg limits, dry density, and hand penetrometer reading.
(l) Dry Density test will also provide wet unit weight and moisture content of sample.

Table A-1 (Continued)

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Proposed Borings and Physical Soil Tests
South Area

Bayou Sorrel Remediation Design

				Analyses Per Boring, Insitu or Disturbed Samples (c)						Analyses Per Boring, Undisturbed Samples (d)						
Boring No.	Purpose(a)	Total Boring Depth (ft)	Total No. of Samples(b)	ASTM D2487/ D2488 Soil Class.	Moisture Content	Atterburg Limits	ASTM D2573 Vane Shear (e),(k)	Specific Gravity (f),(k)	Particle Size Distribution (g),(k)	Hand Penetrometer (h)	Unconfined Compressive Strength	Dry Density (l)	Torvane Shear tests (i),(k)	Triaxial Compressive Strength (k)	Lab Permeability (k)	Consolidation Test (j),(k)
S34	SW,CS	80	16	16	16	2	12 tests in selected South Area borings	3 tests on selected South Area boring samples	10 tests on selected South Area boring samples	6	4	2	8 tests on selected South Area boring samples	6 tests on selected South Area boring samples	10 tests on selected South Area boring samples	4 tests on selected South Area boring samples
S35	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S36	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S37	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S38	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S39	SW,CS	80	16	16	16	2	::	::	::	6	4	2	::	::	::	::
S40	SW,CS	60	12	12	12	2	::	::	::	6	4	2	::	::	::	::
S41	SW,CS	70	14	14	14	2	::	::	::	6	4	2	::	::	::	::
S42	CS,GH	40	8	4	2	1	::	::	::	--	--	1	::	::	::	::
S43	CS,GH	40	8	4	2	1	::	::	::	--	--	1	::	::	::	::
S44	CS,GH	40	8	4	2	1	::	::	::	--	--	1	::	::	::	::
S45	CS,GH	40	8	4	2	1	::	::	::	--	--	1	::	::	::	::
S46	CS,GH	40	8	4	2	1	::	::	::	--	--	1	::	::	::	::

(a) SW = Slurry Wall Design; CS = Cap Settlement Analyses; GH = Hydrogeological Confirmation .
(b) Samples taken every 5 feet of boring depth.
(c) Field extruded Shelby Tube or Split Spoon Sample.
(d) Sealed Shelby Tube shipped to lab.
(e) 4 tests each in 3 selected South Area borings.
(f) Specific gravity (soil particles) on 1 medium stiff and 2 soft clay samples.
(g) Particle size distribution on 2 medium stiff and 2 soft clay samples.
(h) Field test performed on Shelby Tube sample before extrusion or sealing for undisturbed sample.
(i) Torvane shear on 3 medium stiff and 5 soft clay samples. Remolded Torvane shear on same samples.
(j) Consolidation Test on 1 medium stiff clay and 3 soft clay samples.
(k) These samples will also be analyzed for soil classification, moisture content, Atterburg limits, dry density, and hand penetrometer reading.
(l) Dry Density test will also provide wet unit weight and moisture content of sample.

Table A-1 (Continued)

Rev. 3
4/09/87

Proposed Borings and Physical Soil Tests
North Area

Bayou Sorrel Remediation Design

				Analyses Per Boring, Insitu or Disturbed Samples (c)						Analyses Per Boring, Undisturbed Samples (d)						
Boring No.	Purpose(a)	Total Boring Depth (ft)	Total No. of Samples(b)	ASTM D2488 Soil Class.	Moisture Content	Atterburg Limits	ASTM D2573 Vane Shear (e),(k)	Specific Gravity (f),(k)	Particle Size Distribution (g),(k)	Hand Penetrometer (h)	Unconfined Compressive Strength	Dry Density (l)	Torvane Shear tests (i),(k)	Triaxial Compressive Strength (k)	Lab Permeability (k)	Consolidation Test (j),(k)
N47	SW,CS	40	8	8	8	2	12 tests in selected North Area borings	3 tests on selected North Area boring samples	10 tests on selected North Area boring samples	3	3	2	8 tests on selected North Area boring samples	6 tests on selected North Area boring samples	10 tests on selected North Area boring samples	4 tests on selected North Area boring samples
N48	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N49	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N50	SW,CS	50	10	10	10	2	::	::	::	3	3	2	::	::	::	::
N51	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N52	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N53	SW,CS	40	8	8	8	2	::	::	::	3	3	2	::	::	::	::
N54	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N55	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N56	SW,CS	50	10	10	10	2	::	::	::	3	3	2	::	::	::	::
N57	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::
N58	SW,CS	20	4	4	4	1	::	::	::	2	2	2	::	::	::	::

(a) SW = Slurry Wall Design; CS = Cap Settlement Analyses; GH = Hydrogeological Confirmation .
(b) Samples taken every 5 feet of boring depth.
(c) Field extruded Shelby Tube or Split Spoon Sample.
(d) Sealed Shelby Tube shipped to lab.
(e) 4 tests each in 3 selected South Area borings.
(f) Specific gravity (soil particles) on 1 medium stiff and 2 soft clay samples.
(g) Particle size distribution on 2 medium stiff and 2 soft clay samples.
(h) Field test performed on Shelby Tube sample before extrusion or sealing for undisturbed sample.
(i) Torvane shear on 3 medium stiff and 5 soft clay samples. Remolded Torvane shear on same samples.
(j) Consolidation Test on 1 medium stiff clay and 3 soft clay samples.
(k) These samples will also be analyzed for soil classification, moisture content, Atterburg limits, dry density, and hand penetrometer reading.
(l) Dry Density test will also provide wet unit weight and moisture content of sample.

Table A-1 (Continued)

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Proposed Borings and Physical Soil Tests
North Area

Bayou Sorrel Remediation Design

				Analyses Per Boring, Insitu or Disturbed Samples (c)						Analyses Per Boring, Undisturbed Samples (d)						
Boring No.	Purpose(a)	Total Boring Depth (ft)	Total No. of Samples(b)	ASTM D2488 Soil Class.	Moisture Content	Atterburg Limits	ASTM D2573 Vane Shear (e),(k)	Specific Gravity (f),(k)	Particle Size Distribution (g),(k)	Hand Penetrometer (h)	Unconfined Compressive Strength	Dry Density (l)	Torvane Shear tests (i),(k)	Triaxial Compressive Strength (k)	Lab Permeability (k)	Consolidation Test (j),(k)
N59	SW,CS	40	8	8	8	2	12 tests in selected North Area borings	3 tests on selected North Area boring samples	10 tests on selected North Area boring samples	3	3	2	8 tests on selected North Area boring samples	6 tests on selected North Area boring samples	10 tests on selected North Area boring samples	4 tests on selected North Area boring samples
N60	SW,CS	20	4	4	4	1				2	2	2				
N61	SW,CS	20	4	4	4	1				2	2	2				
N62	SW,CS	40	8	8	8	2				3	3	2				
N63	SW,CS	20	4	4	4	1				2	2	2				
N64	SW,CS	40	8	8	8	1				3	3	2				

(a) SW = Slurry Wall Design; CS = Cap Settlement Analyses; GH = Hydrogeological Confirmation .
(b) Samples taken every 5 feet of boring depth.
(c) Field extruded Shelby Tube or Split Spoon Sample.
(d) Sealed Shelby Tube shipped to lab.
(e) 4 tests each in 3 selected South Area borings.
(f) Specific gravity (soil particles) on 1 medium stiff and 2 soft clay samples.
(g) Particle size distribution on 2 medium stiff and 2 soft clay samples.
(h) Field test performed on Shelby Tube sample before extrusion or sealing for undisturbed sample.
(i) Torvane shear on 3 medium stiff and 5 soft clay samples. Remolded Torvane shear on same samples.
(j) Consolidation Test on 1 medium stiff clay and 3 soft clay samples.
(k) These samples will also be analyzed for soil classification, moisture content, Atterburg limits, dry density, and hand penetrometer reading.
(l) Dry Density test will also provide wet unit weight and moisture content of sample.

Table A-2

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Summary of Proposed Borings and Physical Soil Tests

Bayou Sorrel Remediation Design

			Analyses Per Site, Insitu or Disturbed Samples						Analyses Per Site, Undisturbed Samples (b)						
Borings Site Location	Cumulative Depth of Borings	Total No. of Samples	ASTM D2487/ D2488 Soil Class.	Moisture Content	Atterburg Limits	ASTM D2573 Vane Shear(c)	Specific Gravity	Particle Size Distribution	Hand Penetrometer (d)	Unconfined Compressive Strength	Dry Density	Torvane Shear tests	Triaxial Compressive Strength	Lab Permeability	Consolidation Test
South Area	1,690 feet	338	318	308	49	12	3	10	132	88	49	8	6	10	4
North Area	520 feet	104	104	104	24	12	3	10	43	43	36	8	6	10	4
TOTALS	2,210 feet (45 Borings)	442	422	412	73	24	6	20	175	131	85	16	12	20	8

(a) Field extruded Shelby Tube or Split Spoon Sample.
(b) Sealed Shelby Tube shipped to lab.
(c) Field test performed in borehole.
(d) Field test performed on Shelby Tube sample before extrusion or sealing for undisturbed sample.

Table A-3

Physical Soil Testing Methods

Sample Analysis	Analysis Method No. ASTM	Corps of Engineers
Engineering Soil Classification	D2488	
Unified Soil Classification (UCS)	D2487	
Moisture Content	D2216	
Atterburg Limits	D423 & D424	
Vane Shear	D2573	
Specific Gravity	C854	
Particle Size Distribution	D422	
Unconfined Compressive Strength	D2166	
Wet Unit Weight/Water Content	D2216	
Triaxial Compressive Strength	D2850	
Lab Permeability		EM1110-2-1906
Consolidation Test	D2435	

TABLE A-4

Soil/Bentonite Laboratory
Mix Analyses

Mix No.	Mixture Components (% By Weight)		
	% Bentonite (a)	% Excavated Material(b)	% Imported Sand (c)
1	3	77	20
2	3	67	30
3	3	57	40
4	3	47	50
5	4	76	20
6	4	66	30
7	4	56	40
8	4	46	50
9	5	75	20
10	5	65	30
11	5	55	40
12	5	45	50
13	6	74	20
14	6	64	30
15	6	54	40
16	6	44	50

- Laboratory permeability (COE Method EM1110-2-1906) will be performed on each mixture with ground water from site monitoring wells.

- Consolidation Test (ASTM D2435) will be performed on two selected mixes.

(a) Bentonite shall be non-polymer enhanced grade with a 30 to 50 barrel yield per ton at 40 seconds viscosity (Marsh Funnel Test, API 13B Test Procedures).
(b) Composite of boring program samples representative of proposed slurry trench excavation.
(c) Sand obtained from local Bayou Sorrel site region.

APPENDIX B

Proposed Geotechnical Sampling and Physical Tests for Soil Borrow Areas

APPENDIX B

PROPOSED GEOTECHNICAL SAMPLING AND PHYSICAL TESTS FOR SOIL BORROW AREAS

BAYOU SORREL REMEDIATION DESIGN

Objectives

The objectives of the proposed geotechnical program for designated soil borrow areas at the project site are:

- Confirmation of selected borrow areas as adequate sources of clay, topsoil and fill material for cap construction.
- Confirm soil type and suitability of proposed runoff pond excavations for cap topsoil cover and/or clean fill.
- Characterize geotechnical properties of borrow clay for cap construction design and quality control.

Scope

Figure B-1 indicates the site location of proposed borings or surface samples at selected borrow pits areas and at the proposed location of the South and North Runoff Ponds. Five borings (25 feet deep) will be made at the North and East borrow pit sites; shallow (two to three feet deep) hand auger sampling will be performed at the two runoff pond sites. Table B-1 lists the proposed sample frequency and schedule of analyses to be performed on each boring sample.

In addition to geotechnical borings at the two borrow pits, one temporary piezometer will be installed at each pit for measurement of ground water levels at the end of the day and 24 hours and 48 hours later.

Drilling and Sampling Procedures

Subject to access, above/below ground obstructions, and site specific stratigraphy, all borings for the borrow pit sites will be advanced by dry drilling with hollow stem augers. All boring samples (borrow pits) will be collected using Shelby tubes unless split-spoon samplings is required in non-cohesive soil stratas. Each sample will be extruded from the Shelby tube onto clean PVC trays. The ERM-Southwest hydrogeologist will log the core sections for each boring and select the necessary samples

for physical testing. These samples will be wrapped tightly in aluminum foil, then bagged in heavy duty plastic-type bags and placed in boxes for shipment or storage. Samples for physical testing will be selected after in-house review of boring logs.

All borrow pit borings will be logged in the field by the ERM-Southwest hydrogeologist who will make note of all soil strata, supervise the collection of Shelby tube samples, select and bag soil samples for further analyses, and make note of soil/water conditions, existence of wood, color and textural changes and other important information as drilling proceeds. After completion of each borrow pit boring, the borehole will be backfilled with drilling cuttings.

Shallow surface samples at the runoff pond locations will be obtained with hand-augers. The ERM-Southwest hydrogeologist will note sample texture, color and soil/water conditions.

U.S. Soil Conservation Service (SCS) soil data for the Iberville Parish (in the area of the project site) will be used to define the depth of topsoil to be used for cap construction. Topsoil will include the depth of soil defined as the A horizon, and possibly the upper depth of the B horizon, based on the visual SCS soil classification criteria.

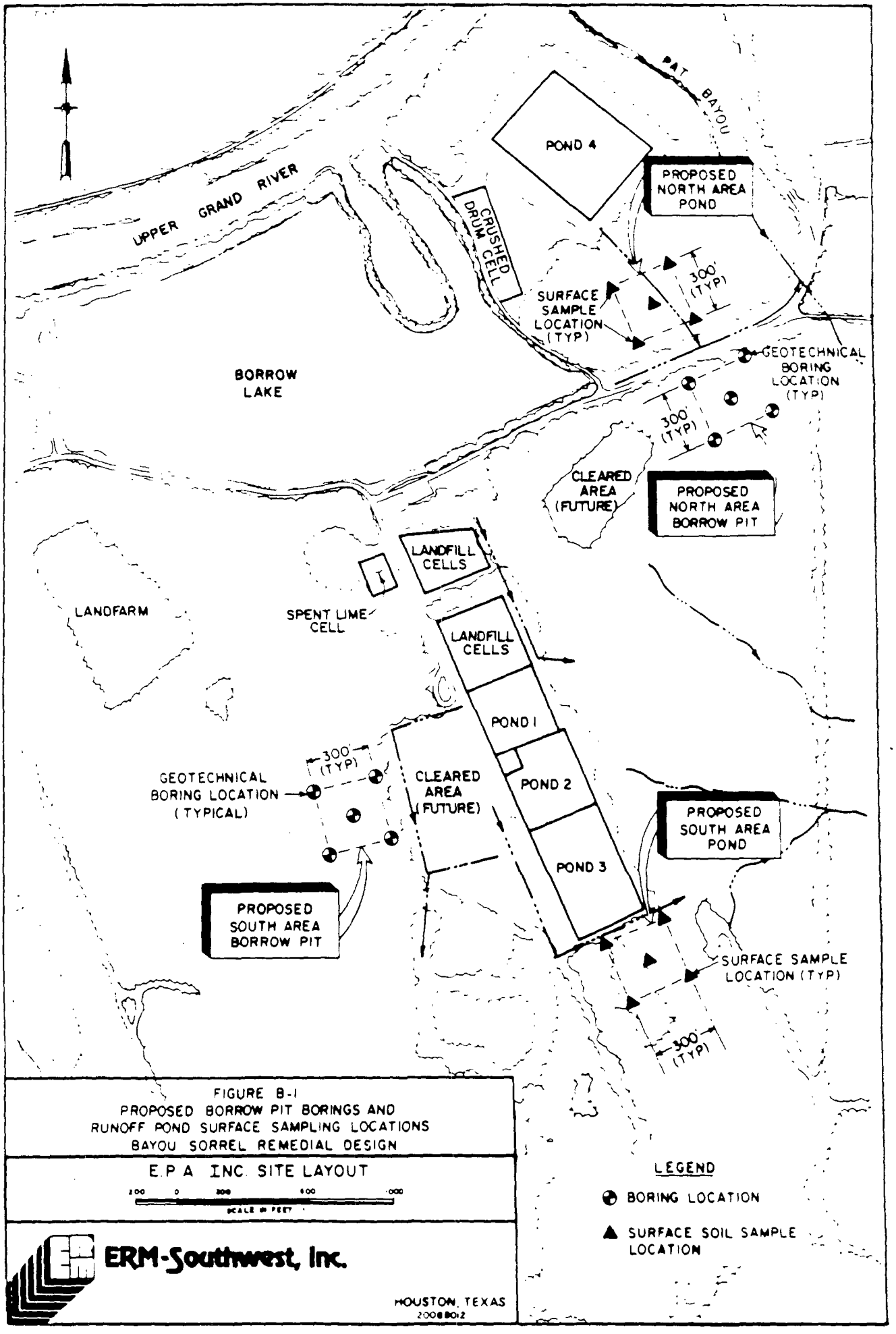


FIGURE B-1
PROPOSED BORROW PIT BORINGS AND
RUNOFF POND SURFACE SAMPLING LOCATIONS
BAYOU SORREL REMEDIAL DESIGN

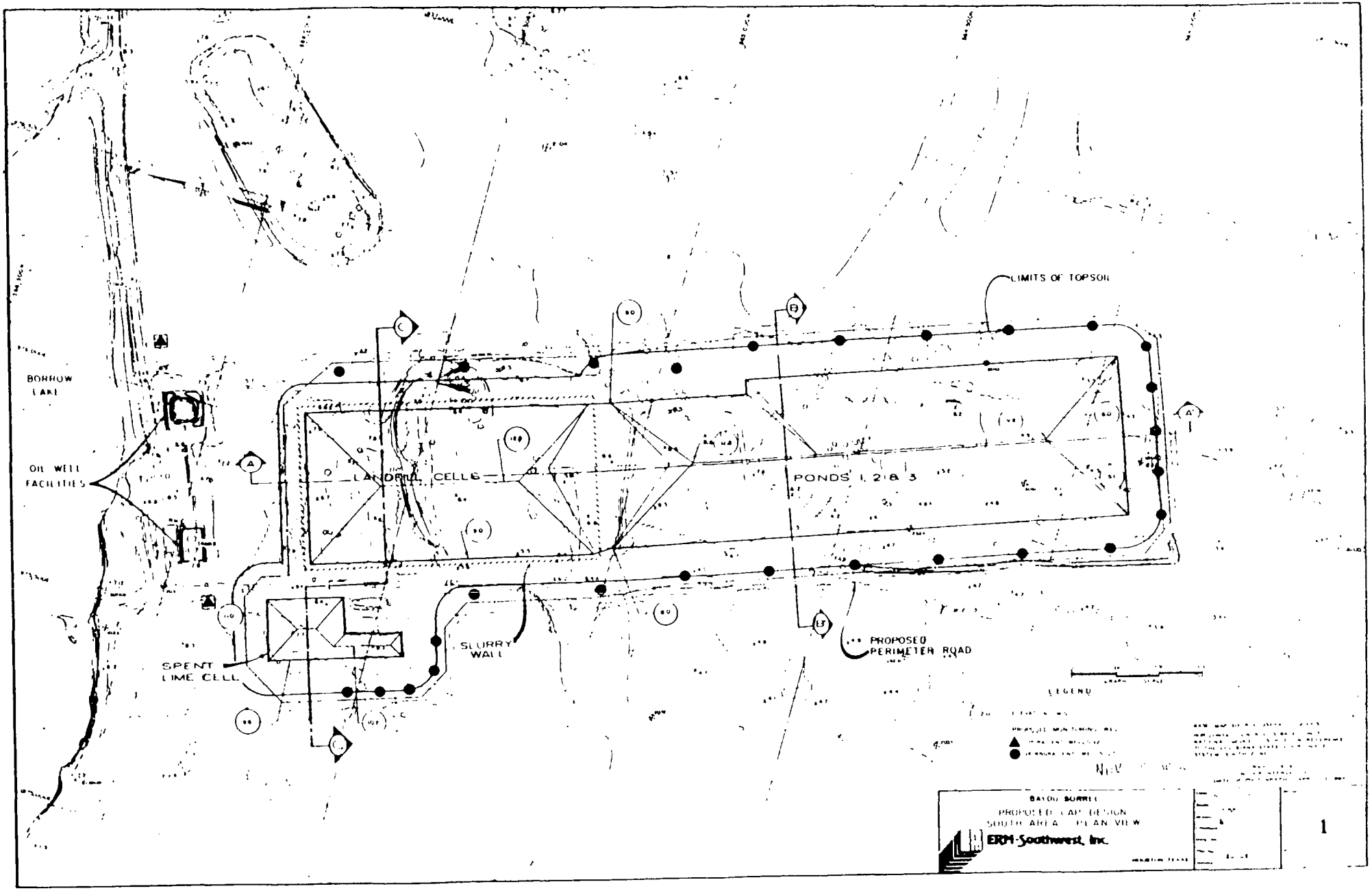
TABLE B-1

Proposed Geotechnical Sampling & Physical
Soils Tests For Soil Borrow Areas

Bayou Sorrel Remediation Design

Borrow Site	No. of Borings or Sample Locations Per Site	Boring Depth	Depth of Samples	Total Samples Per Site	Analyses Per Borrow Site: USC Soil Class.	Moisture Content	Dry Density	Atterburg Limits	Particle Size Distribution	Standard Proctor Density Curve(e)	Lab Permeability(d)
300 ft. square plot approx. 500 ft. east of Pond 1 & 2	5 (a)	25'	2.5',5',7.5',10', 12.5',15',20',25'(b)	40	15	15	15	15	15	3	3
300 ft. square plot approx. 1200 ft. south of Pond 4	5 (a)	25'	2.5',5',7.5',10', 12.5',15',20',25'(b)	40	15	15	15	15	15	3	3
300 ft. square plot south of Pond 3 (proposed South Runoff Pond location)	5 (a)	--	2' (c)	5	5	--	--	5	5	--	--
300 ft. square plot southeast of Pond 4 (proposed North Runoff Pond location)	5 (a)	--	2' (c)	5	5	--	--	5	5	--	--
			Analyses Totals	50	40	30	30	40	40	6	6

(a) 5 boring or sample locations at each site, one at each corner of plot and one in the center of plot.
(b) Field extruded Shelby Tube or split spoon samples.
(c) Hand auger samples.
(d) Constant head permeability at 95% Standard Proctor Density, 0-4% wet of optimum moisture content.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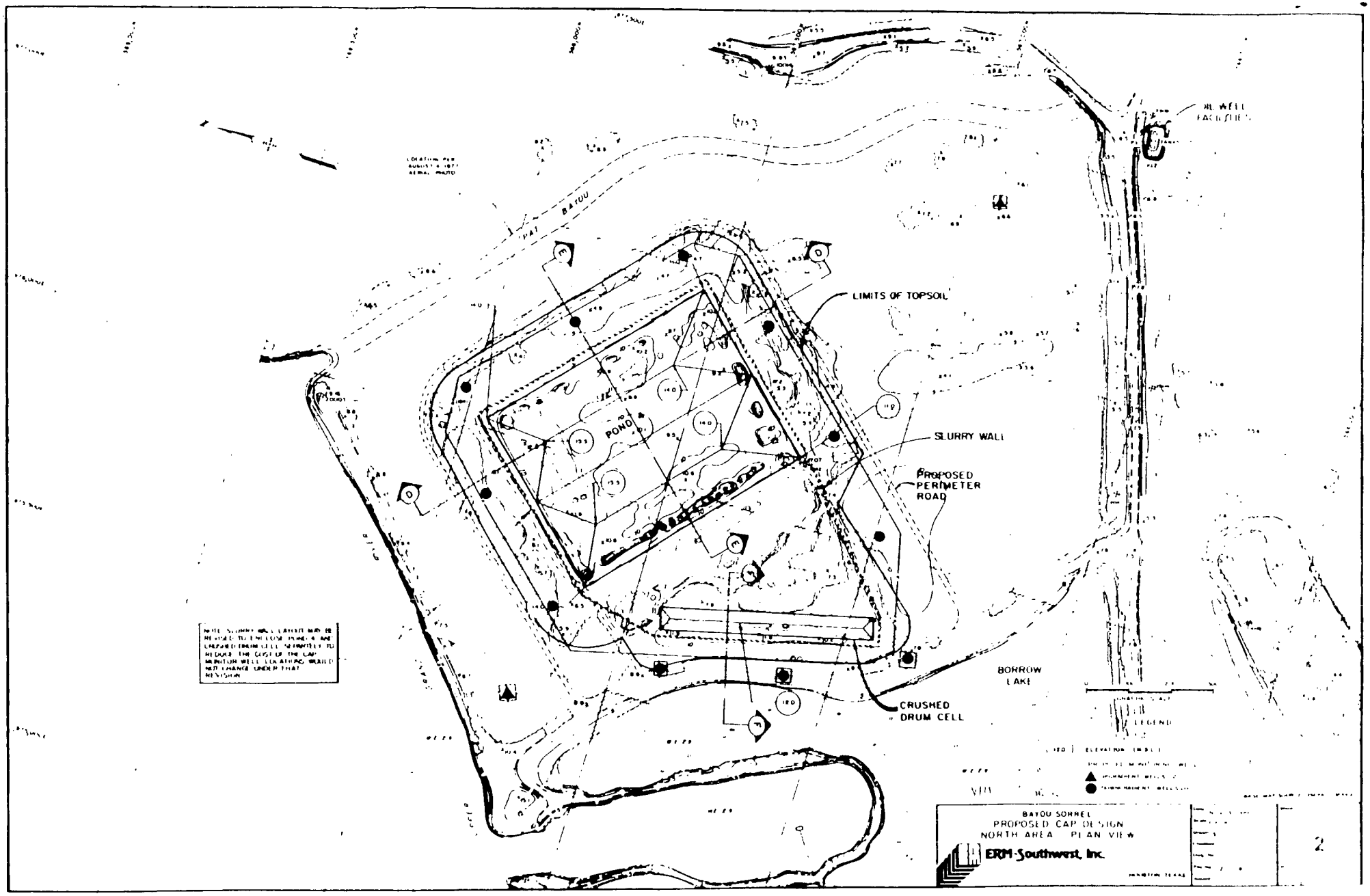
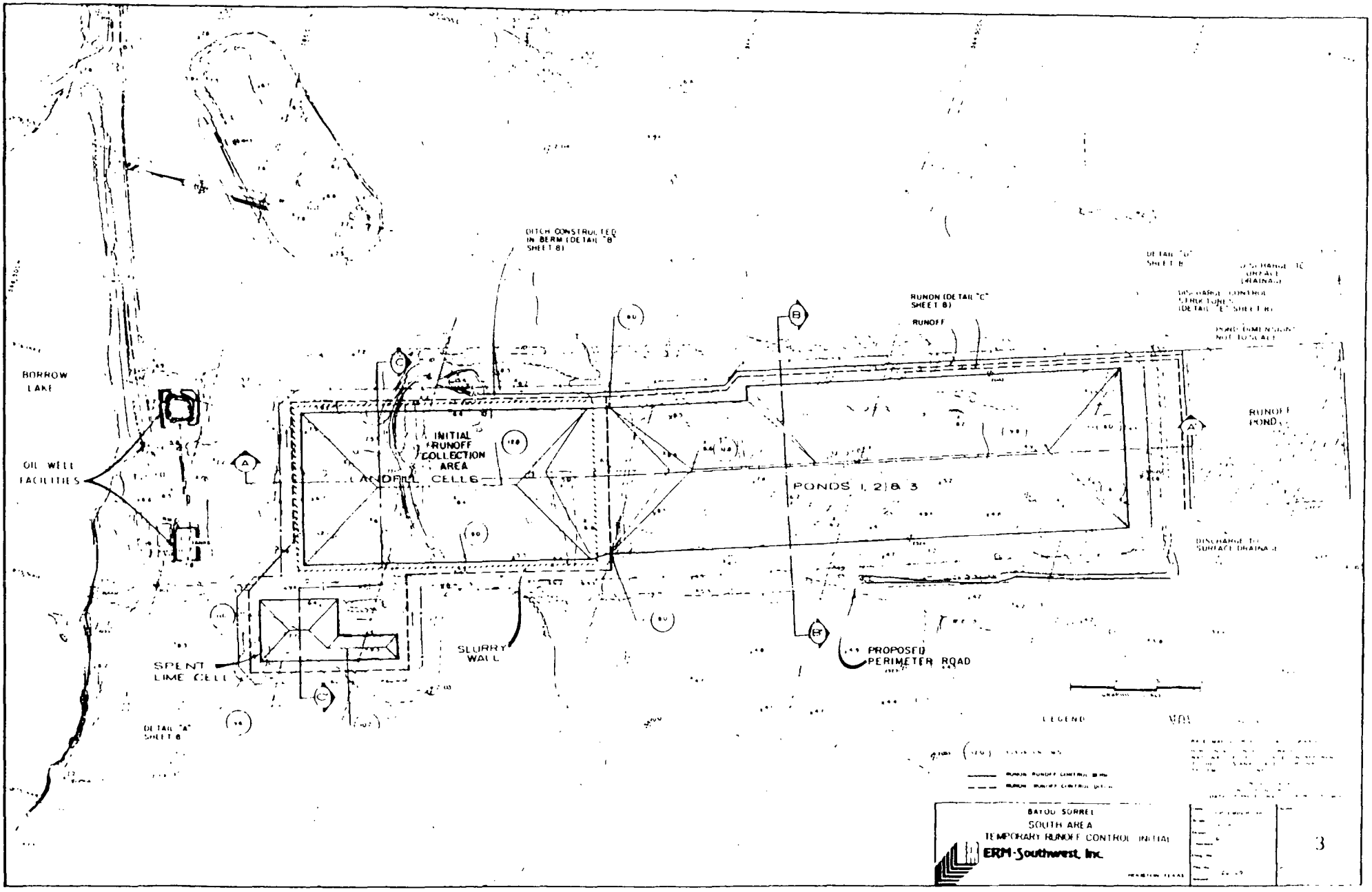
BORROW LAKE
OIL WELL FACILITIES
LANDFILL CELLS
PONDS 1, 2 & 3
SLURRY WALL
SPENT LIME CELL
PROPOSED PERIMETER ROAD
LEGEND
BAYOU BORREE
PROPOSED CAP DESIGN
SOUTH AREA - PLAN VIEW
ERM-Southwest, Inc.

1


LIMITS OF TOPSOIL
SLURRY WALL
PROPOSED PERIMETER ROAD
POND
BORROW LAKE
CRUSHED DRUM CELL
BAYOU SORREL
PROPOSED CAP DESIGN
NORTH AREA PLAN VIEW
ERM-Southwest, Inc.
2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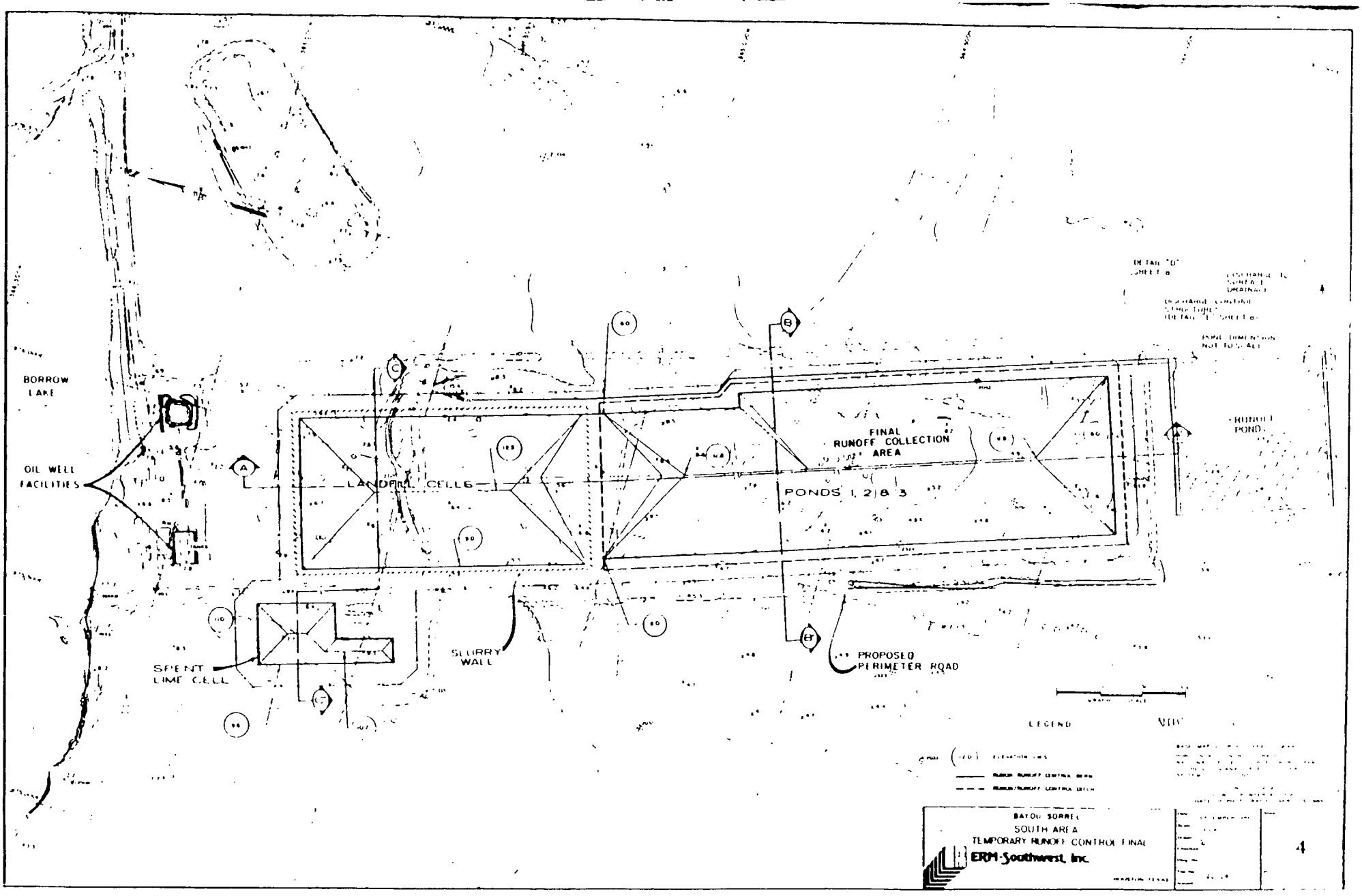
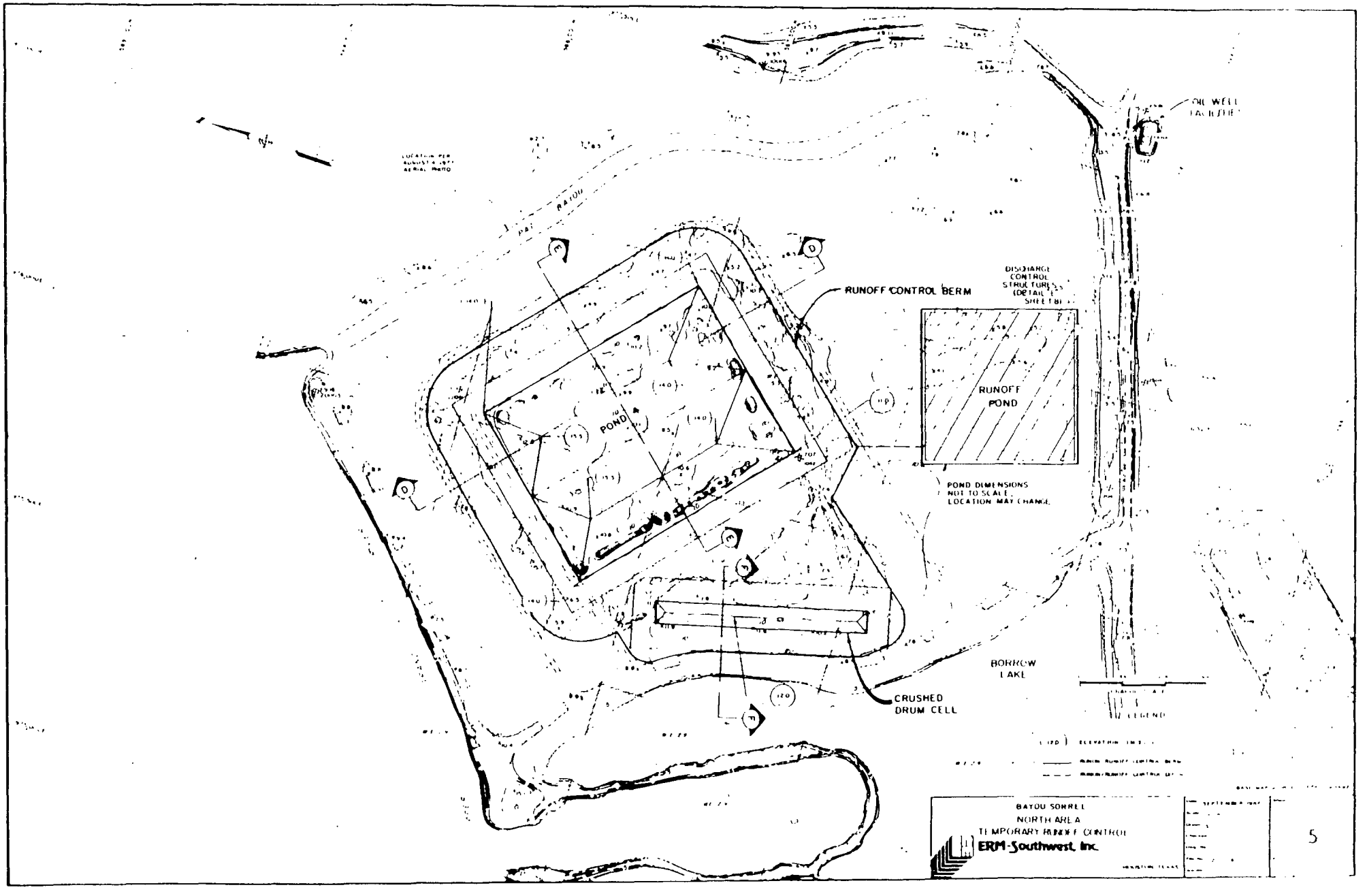
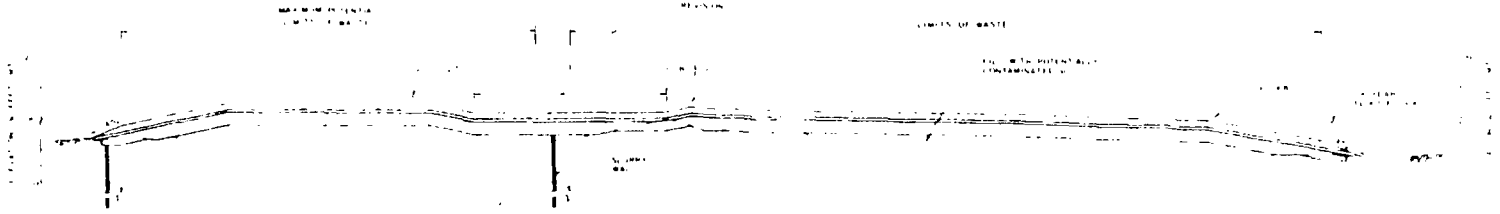
OIL WELL FACILITIES
INITIAL RUNOFF COLLECTION AREA
LANDFILL CELLS
PONDS 1, 2 & 3
RUNOFF POND
SPENT LIME CELL
SLURRY WALL
PROPOSED PERIMETER ROAD
RUNOFF
BAYOU SORREL
SOUTH AREA
TEMPORARY RUNOFF CONTROL INITIAL
ERM-Southwest, Inc.
3

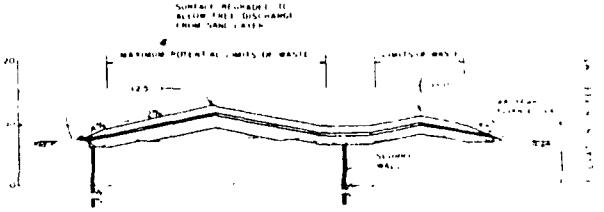

BORROW LAKE
OIL WELL FACILITIES
LANDFILL CELLS
FINAL RUNOFF COLLECTION AREA
PONDS 1, 2 & 3
RUNOFF POND
SPENT LIME CELL
SLURRY WALL
PROPOSED PERIMETER ROAD
LEGEND
BAYOU SORREL
SOUTH AREA
TEMPORARY RUNOFF CONTROL FINAL
ERM-Southwest, Inc.
4


RUNOFF CONTROL BERM
DISCHARGE CONTROL STRUCTURES (DETAIL E SHEET 8)
RUNOFF POND
POND DIMENSIONS NOT TO SCALE LOCATION MAY CHANGE
POND
BORROW LAKE
CRUSHED DRUM CELL
BAYOU SORREL
NORTH AREA
TEMPORARY RUNOFF CONTROL
ERM-Southwest, Inc.

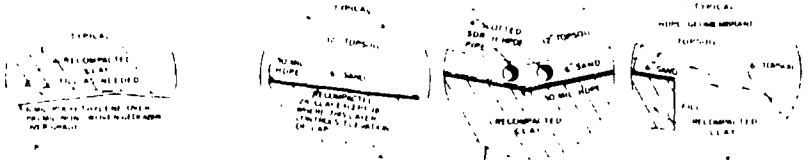


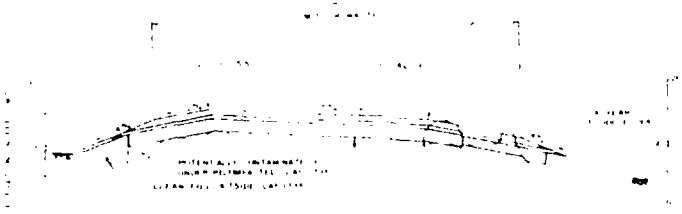
SECTION A-A'
SOUTH AREA

SECTION B-B'
SOUTH AREA



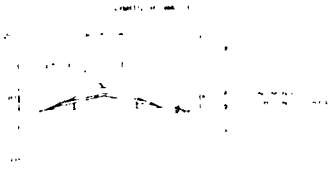
SECTION C-C'
SOUTH AREA





SECTION D-D'
NORTH AREA

SECTION E-E'
NORTH AREA

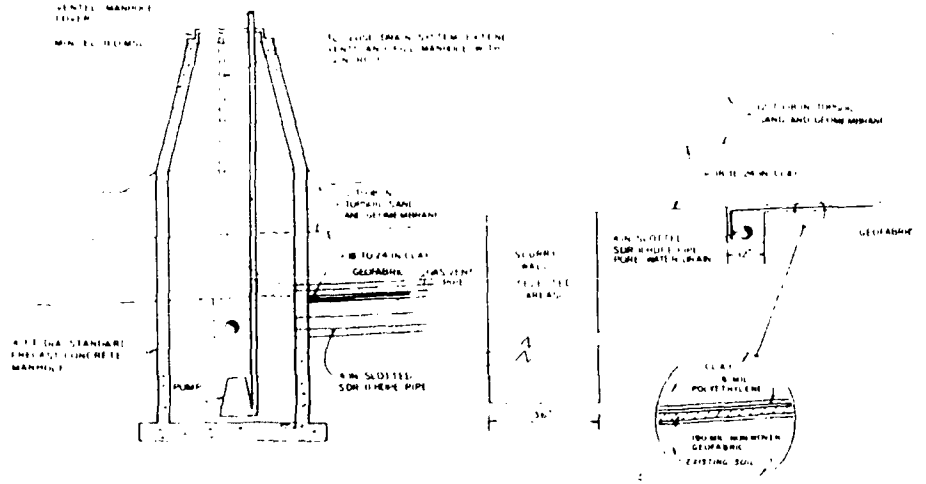


SECTION
NORTH AREA

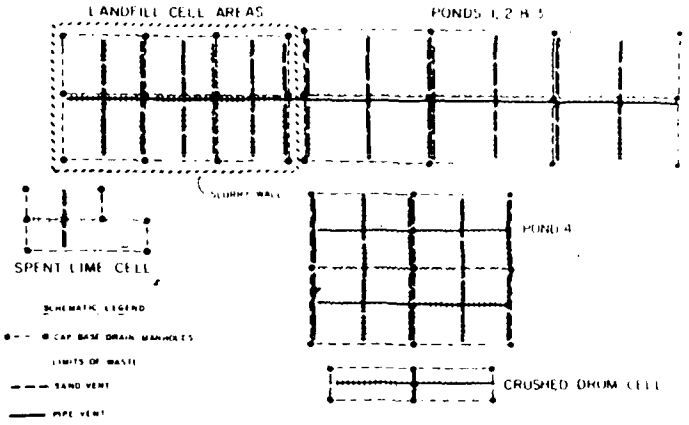
BAYOU SORREL
PROPOSED CAP DESIGN
CROSS SECTIONS

ERM-Southwest, Inc.

6

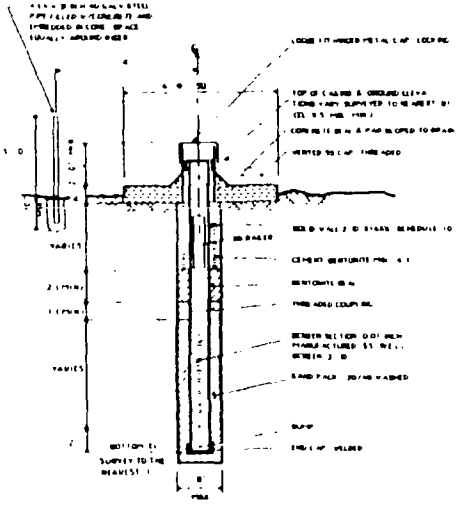


CAP BASE DRAIN DETAILS

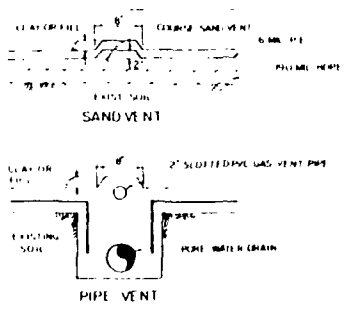


SCHEMATIC LAYOUT OF DRAINS

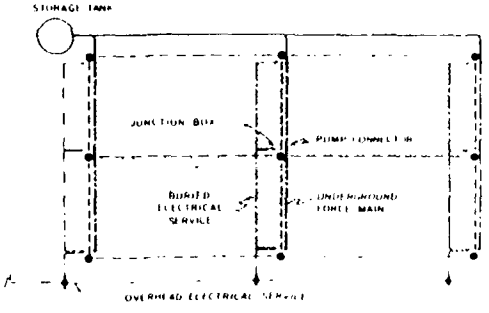
NOT TO SCALE



GENERAL MONITOR WELL CONSTRUCTION DETAIL



CAP BASE GAS VENT DETAILS

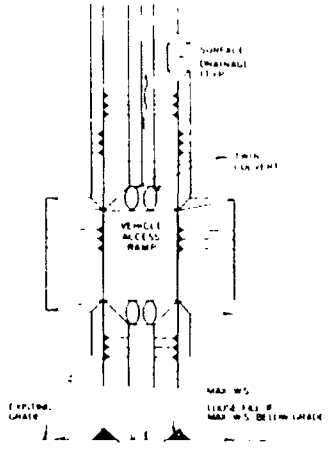


TYPICAL DRAIN UTILITIES LAYOUT

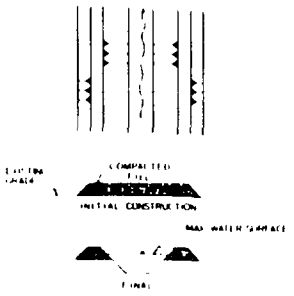
BAYOU SORREL

CAP BASE DRAIN AND VENT DETAILS
MONITOR WELL DETAILS

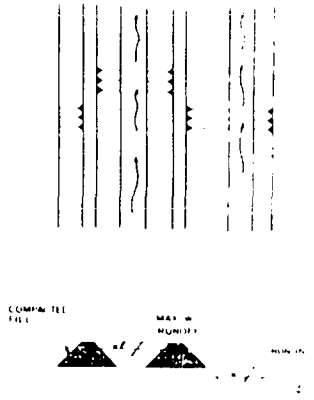
ERM-Southwest, Inc.



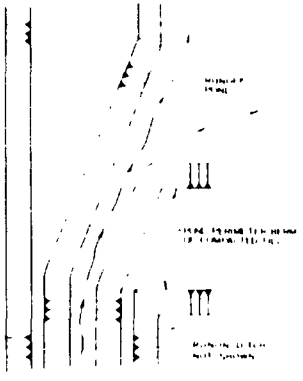
DETAIL "A"
RUNOFF COLLECTION AREA
PERIMETER DRAIN



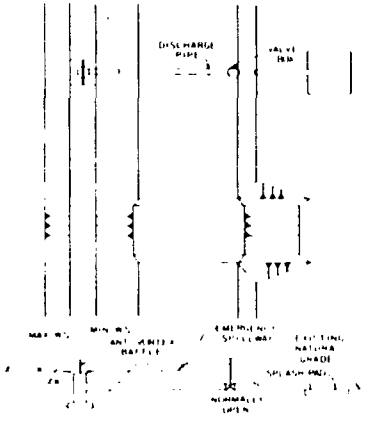
DETAIL "B"
RUNOFF TRANSPORT DITCH
CONSTRUCTED IN BERM



DETAIL "C"
RUNON CONTROL



DETAIL "D"
RUNOFF TRANSPORT DITCH
TERMINUS AT RUNOFF POND



DETAIL "E"
RUNOFF DISCHARGE
CONTROL STRUCTURES

BAYOU SORREL
TEMPORARY RUNOFF CONTROL
DETAILS
ERM-Southwest, Inc.

ADDENDUM A

REMEDIAL CONCEPT DESIGN

BAYOU SORREL SITE
IBERVILLE PARISH, LOUISIANA

July 15, 1987

W.O. #20-08

Prepared By:

ERM-Southwest, Inc.
16000 Memorial Drive, Suite 200
Houston, Texas 77079
(713) 496-9600

ADDENDUM A

REMEDIAL CONCEPT DESIGN

BAYOU SORREL SITE
IBERVILLE PARISH, LOUISIANA

This is the concept design to implement the remedial alternative selected in the approved Record of Decision (ROD) dated November 14, 1986.

1. Description

This concept design includes the capping of all waste areas with a slurry wall being placed around the Landfill Cell Area, Pond 4 and the Crushed Drum Cell. The caps consist of geofabric, fill, 18 to 24 inches of recompacted clay, a 30 mil geomembrane, 6 inches of sand, 12 to 18 inches of topsoil, and seeding with grass. The slurry wall will be integrated with the cap perimeters. Clay and topsoil will be obtained from on-site borrow pits. The landfarm or cleared areas will not be covered.

Wastes outside the capped areas will be placed under the caps. If additional fill material is needed under the caps, affected soils will be used to the extent available. The completed caps will be fenced and roads will placed around the perimeters of the waste areas.

1.1 Stormwater Runoff Control

Construction will be managed to assure that stormwater will not come in contact with the waste. Any time waste is to be excavated or exposed, the contractor will have clean clay-rich soil stockpiled near the excavation such that it can rapidly be placed over the exposed waste in the event of threatening rain. All waste will be covered at the end of each workday.

Slurry trench construction will be carefully managed to prevent any significant impact on stormwater runoff. The slurry mixing area will be limited in size. Runoff from the diked slurry mixing area will be used as make-up water in the mixing of soil-bentonite slurry. Excess runoff will be routed through the stormwater control system or disposed of off-site as a non-hazardous liquid provided it meets the requirements of 40 CFR Part 261 Subpart C. Excess soils from slurry wall construction will be placed on the areas being encircled by the slurry walls. The excess soil will be covered with clean soil daily and will eventually be utilized within the finished cap as fill.

Stormwater runoff from construction areas will thus be unaffected by waste. This stormwater will be collected and routed to a variable-level flow-through runoff pond to remove erosion sediment. The overflow will be sampled once during each rainfall event (maximum of once per day when discharging) and analyzed for a slate of analyses. In the event that any agreed-upon water quality parameters are exceeded, construction will be halted until measures are taken to ensure that stormwater quality remains within the agreed upon limits.

The stormwater runoff will be sampled during any construction involving exposure of waste or affected soils. Following completion of construction, stormwater runoff will be sampled quarterly for three years and semi-annually for two years and once every five years for the remaining twenty-five years.

1.2 Porewater Monitoring and Disposal

A porewater collection system has been designed to collect porewater which is expected to be generated during consolidation of the soils under the proposed caps. Consolidation should be essentially complete in less than five years and therefore no more porewater should be generated after that time.

The BSTF will collect and dispose off-site of all porewater which is collected in the system during the first five years following completion of construction, except that when the flood waters are above the level of the lowest part of each porewater collection system, the pumps will be shut off. In this manner, no attempt will be made to remove the high volume flood waters which will probably enter the porewater collection system if it is kept dewatered. After consolidation of the soils under the caps is complete (i.e., equilibrium conditions have been re-established), there will probably be water collected by the system during the high ground water conditions which occur at the site each spring.

Records will be kept relative to quantities of porewater removed by month. Additionally, bench marks will be established at various points on the caps to monitor settlement versus time. Quarterly, samples of the porewater will be analyzed for TOC, pH, and specific conductance (SC) or total dissolved solids (TDS).

After five years of off-site disposal of porewater collected by the system, the data collected will be used to evaluate the need for continued removal of water from the porewater system. This evaluation will consider data collected showing that consolidation of the soil (and thus generation of additional porewater) has essentially been completed and equilibrium conditions reached.

The porewater will be further tested for RCRA 40 CFR Part 261 Subpart C hazardous waste characteristics. Assuming the porewater does not fail these characteristics, the water will not be considered a hazardous waste. Therefore, in accordance with EPA's CERCLA off-site disposal policy (50 FR 45933-45937, II, II, B, 3, Nov. 5, 1985), the porewater may be disposed in a RCRA commercial hazardous waste facility. This will allow use of facilities such as the Rollins underground injection well located seven miles from the site in the town of Bayou Sorrel.

1.3 Ground Water Monitoring

A ground water monitoring system consisting of 42 stainless steel monitoring wells will be installed within three months following completion of construction. The wells spacing will be 300 ft. around the slurry wall areas at Pond 4, the Crushed Drum Cell and Landfill Cell Areas, 200 ft. apart around Ponds 1, 2 & 3, 100 ft. apart at the south end of Pond 3 and 75 ft. apart around the Spent Lime Cell. Prior to installing the wells around Ponds 1, 2 and 3, a geotechnical boring program will be conducted utilizing borings 50 ft. apart (except where previous borings have been installed).

The ground water monitoring wells include two upgradient wells for the south area and two "upgradient" wells for the north area.

One deep monitor well will be replaced. There are presently four existing "deep" monitor wells that are screened in the Plaquemine Aquifer, as follows:

Well No.	Location	Installer
11-D	Landfill Cell Area	ERM-Southwest
14-D	Pond 3	ERM-Southwest
15-D	Pond 4	ERM-Southwest
D-1	Site Entrance	EPA

EPA considers monitor well 14-D not to be sufficiently deep to monitor the Plaquemine Aquifer. Monitor well 14-D will be plugged and abandoned, and replaced with a new deep monitor well farther south.

The Bayou Sorrel site-specific statistical procedure to monitor the site during the 30-year monitoring period is included in the Bayou Sorrel Statement of Work as Attachment B. The proposed ground water statistics performance standards will be included in the Bayou Sorrel Consent Decree as an addendum to an attached Statement of Work.

An extensive continuing sampling and analysis effort is proposed below for monitoring ground water, stormwater, runoff and porewater generation. The aggregate sampling and analysis program is summarized in Table 1, attached.

Following completion of construction and collection of additional ground water level data, the BSTF may request EPA to allow modification of sampling of any "downgradient" wells which can be shown to be no longer downgradient of the wastes. Should this request be granted, water level measurements would continue to be obtained from these exempted wells and the data plotted along with the other water level data from the site. If any of the exempted wells are found at a later date to be downgradient due to changing geohydrological conditions, sampling and analysis will be resumed at that well in accordance with the Ground Water Statistics Plan.

2. Overall Concepts

The major elements of the remedial action and their functions are:

2.1 Cap

Grass	Controls erosion and provides evapotranspiration of soil moisture.
Topsoil	Sheds rainwater; supports grasses for maximum evapotranspiration and erosion control.
Sand	Provides lateral drainage; protects geomembrane.
30 mil HDPE Geomembrane	Serves as a water barrier and provides increased protection to underlying recompacted clay layer from drying and cracking.

TABLE 1

Summary of Sampling and Analysis Scope
at Bayou Sorrel Site

	Construction Phase (Yr.)		Post-Construction Phase (Yr.)						Total Samples For Analysis
	1	2	1	2	3	4	5	6-30	
Active Construction (Mo.)									
North Area	7	7							
South Area	7	7							
GROUND WATER MONITORING[e]									
Shallow Wells									
Upgradient shallow wells			4	4	4	4	4	4	
Downgradient shallow wells			38	38	38	38	38	38	
Total wells			42	42	42	42	42	42	
Sample events per year			4	2	2	2	2	1	
Upgradient replicates			3	1	1	1	1	1	
Downgradient replicates			1	1	1	1	1	1	
Field blanks per event			3	3	3	3	3	3	
Field duplicates per event			3	3	3	3	3	3	
Samples for analysis									
Tables 3 and 4 organics			42				42	42/5 Yr[d]	294
Table 5 detection monitoring par's			224	96	96	96	96	48	1808
Deep Wells	4	4	4	4	4	4	4	4	
Sample events			1				1	1/5 Yr	
Samples for analysis									
Priority Pollutants			4				4	4/5 Yr	88
STORMWATER RUNOFF CONTROL									
Ditch discharge samples/event			2	2	2	2	2		
Pond discharge samples/event	2	2							
Maximum frequency of events									
Flow, TOC, COD, O & G, TSS	1/Day	1/Day	1/Q	1/Q	1/Q	2/Yr	2/Yr		
Samples for analysis (typical[a])	64	64	8	8	8	4	4		202
As, Cd, Ni, CN	1/Wk	1/Wk	1/Q	1/Q	1/Q	2/Yr	2/Yr		
Samples for analysis (typical[a])	42	42	8	8	8	4	4		158
Priority Pol. Metals, Organics	1/Mo	1/Mo	1/Q	1/Q	1/Q	2/Yr	2/Yr	1/5 Yr	
Samples for analysis (typical[a])	14	14	8	8	8	4	4	2/5 Yr	78
PORE WATER COLLECTION (SOUTH AREA)									
Sample events per year	4	4	4	4	4	4	4[b]		
Samples for analysis									
TOC, pH, SC or TDS	4	4	4	4	4	4	4[b]		32
									2600[c]

NOTES:

[a] 1977 rainfall events $\geq$ 0.25 in., during construction months.

[b] follow with data evaluation.

[c] approximately 67,000 water surface and water quality data points.

[d] 42 every five years

[e] Water levels will be recorded in shallow and deep monitor wells semi-annually through the post-construction phase.

3/18/87

	Recompacted Clay Layer	Serves as a water barrier if geomembrane is eventually breached; use on-site source.
	Fill	Fills void between recompacted clay and geomembrane/geofabric; use existing cap soil, wastes located outside the capped areas, landfarm soil, excess soil from slurry trench; recompact.
2.2	Cap Base System	
	Geomembrane	Prevents blinding of geofabric by clay above.
	Geofabric	Intercepts and collects upward movement of porewater (mobilized by consolidation due to cap overburden) and gas migration; also structural reinforcement for existing soils during cap placement.
	Drains	Collect porewater and gas from geofabric.
	Vents	Collect gas from geofabric.
2.3	Slurry Wall	Reduces ground water migration into and out of waste area.
2.4	Fence	Prevents trespassing.
2.5	Road	Provides convenient vehicular access to areas surrounding caps.
2.6	Temporary Runon/Runoff Control	
	Runon/Runoff Control Berms and Ditches	Change natural drainage patterns to isolate runoff from construction areas where waste is being exposed.

Runoff Pond	Detains runoff from construction areas where waste is being exposed, allowing sediment to settle before discharge.
Runoff Discharge	Sampled and analyzed during each rainfall event that produces measurable discharge, but no more than once per 24-hours when discharging. Analyses to be performed as in Table 2.

2.7 Disposal of Solid Wastes Located Outside Capped Areas

Wastes Included	Wastes on surface near the entrance gate; Wastes on the surface near Pond 4; Drummed solids from the EPA's field activities. Miscellaneous pipe from the site area.
Means of Location	Visual, HNU meter, H_2S meter.
Disposition	Excavated and placed under clean fill in designated areas to be capped; drummed solids to be emptied and drums crushed.

2.8 Disposal of Porewater and Drummed Liquid Wastes

Wastes Included	Porewater generated during consolidation; drummed drilling fluids and ground water from EPA's field activities.
Disposition	RCRA permitted commercial disposal facility. Since wastes are not RCRA hazardous wastes, disposal site does not have to be CERCLA approved. This is provided for in 50 FR 45933-45937, II, II, B, 3 (Nov. 5, 1985). Drums to be crushed and placed under clean fill in designated areas to be capped.

TABLE 2

RUNOFF DISCHARGE QUALITY

Water Quality Parameter	Maximum Allowable Concentration* (mg/l)	Analytical Frequency** (one per)
Flow (MGD)	Report	Day
Total Organic Carbon (TOC)	50	Day
Chemical Oxygen Demand (COD)	100	Day
Oil and Grease	15	Day
Total Suspended Solids (TSS)	Report	Day
Arsenic	0.1	Week
Cadmium	0.1	Week
Nickel	0.5	Week
Total Cyanide	0.1	Week
Priority Volatile Organics***	0.1	Month
Priority Acid Extractable Organics***	0.1	Month
Priority Base/Neutral Extractable Organics***	0.1	Month
Priority Pesticides/PCB's***	0.005	Month

The pH to be 6.0 to 9.0 standard units and shall be monitored no more than once per day during each discharge event.

There shall be no discharge of floating solids or visible foam in other than trace amounts.

* Study of background stormwater quality may be performed by BSTF to establish need for higher discharge limits because of higher background levels.

** During a measurable discharge event.

***Shown in Table 3.

3. Design Basis

3.1 Cap

Outer Limits	Intercept natural grade (restored grade in Pond 4).
Controlling Grade of Cap Surface	2%, except 4% beyond limits of waste.
Grass	Coastal Bermuda and Annual Ryegrass.
Topsoil Depth	12" to 18"; depth of topsoil to be determined; bottom 6 to 12 inches may be of lesser quality than top 6 inches.
Clay Layer Depth	24 inches except 18 inches minimum where clay layer depth controls cap elevation.
Clay Layer Permeability	10^{-7} cm/sec or less.

3.2 Cap Base System

Required Life	5 years or until consolidation ends.
Contaminated Water Volume	
Porewater Release	2,900,000 gal. total over 3-4 years.
Ground Water	Negligible.
Gas Volume	No basis for calculation.
Geomembrane	6 mil polyethylene.
Geofabric	190 mil non-woven polypropylene
Drains	4 in. slotted SDR 11 HDPE pipe bedded in coarse sand.
Vents	Coarse sand or 2 in. slotted PVC pipe bedded in coarse sand.

Collection Manholes	4 ft. diameter precast reinforced concrete with cast-iron covers and rings; top of concrete 1.5 ft. above 100-year flood.
Pumps	3-5 gpm, submersible, on level control.
Electrical	Buried PVC or aluminum conduit.
Force Mains	4 in. HDPE in below-ground trenches.
Holding Tanks	3 at 20,000 gallons each, with geomembrane-lined earthen berms. Tank base located above 100-year flood level.

3.3 Slurry Wall

Width	3 ft.
Depth	Generally 35-45 ft. around landfill cell area and 12-15 ft. around Pond 4 and Crushed Drum Cell. Final depth to be decided during detailed design following geotechnical boring program.
Excavation Procedure	Backhoe
Backfill Mixing Procedure	Bulldozer
Fines (smaller than #200 sieve) in Backfill	25%, minimum.
Estimated Imported Fines Required	0%
Percent Dry Bentonite in Backfill	2% minimum.
Slurry Density	70-80 lbs./ft^3

Slurry Viscosity (Marsh funnel @ 65° F)	43 sec/946 cm^3
Backfill Slump (ASTM Std. C-143-78)	6-7 inches
Slurry Head During Excavation	4 ft. min. above ground water level.
Permeability	10^{-7} cm/sec. or less.

3.4 Fencing

6 ft. high galvanized chain link fence with 3-strand barbed wire on top. RCRA warning signs at 400 ft centers and at gates.

3.5 Roadway Design

Service	Post-Construction, light duty.
Crown	1/4 in. per ft.
Minimum Height, Roadway Centerline to Ditch Flowline	2.5 ft.
Maximum Grade	8%
Minimum Turning Radius, Outside	50 ft.
Width	12 ft.
Composition	8 in. crushed stone over ground stabilization fabric.

3.6 Temporary Runon/Runoff Control

Runon/Runoff Ditches

Peak Flow	5-year, 0.5-hour storm, modified per SCS Curve 90 for poor grass, clay-rich soil.
Peak Velocity	4 ft. per sec.

Runon/Runoff Berms

Height	Contain 5-year, 24-hour storm, modified per SCS Curve 90 for poor grass, clay-rich soil.

Runoff Ponds

Number	1 each, North and South areas.
Volume	1.0 acre-inch per acre of controlled construction area.

Drainage Area

North Pond	18 Acres.
South Pond	11 Acres.

Pond Dimensions

North Pond	280 ft. x 280 ft. x 0.8 ft. deep.
South Pond	140 ft. x 140 ft. x 2.0 ft. deep.
Discharge Pipe	Variable flow. Design volume discharged in 24-hours.
Emergency Spillway	Discharge 5-year, critical duration storm, modified per SCS Curve 90 for poor grass, clay-rich soil, discharge pipe blocked.

3.7 Ground Water Monitoring

Monitor Wells, North Area, Shallow

Number	13 including two "upgradient" (See Drawing No. 2).
Spacing	300 ft., center-to-center; approximately 75 ft. from slurry wall.

Diameter	2 in.
Screened	1 10 ft.; 4.0 to -6.0 ft. MSL.
Depth	About 17 ft. including 2 ft. silt trap below screen.
Construction	Schedule 10, 316 Stainless Steel, flush jointed; carbon steel protective casing; 6 ft. X 6 ft. concrete pad; dedicated bailer.
Top of Casing Elevation	11.0 ft. MSL minimum.

Monitor Wells, South Area, Shallow

Number	29 including 2 upgradient (See Drawing. No. 1).
Spacing	
Landfill Cell	300 ft. center-to-center; 75 ft. from edge of slurry wall.
Ponds, 1, 2 & 3	200 ft. center-to-center; 75 ft. from edge of waste.
South End of Pond 3	100 ft. center-to-center; 75 ft. from edge of waste.
Spent Lime Cell	75 ft. center-to-center; 75 ft. from edge of waste.
Diameter	2 in.
Screened Interval	5 ft. at top of transmissive zone or 10 to 20 ft. where transmissive zone is absent.
Depth	Variable from 18 to 30 ft. including 2 ft. silt trap below screen.

Construction	Schedule 10, 316 Stainless Steel, flush jointed; carbon steel protective casing; 6 ft. X 6 ft. concrete pad; dedicated bailer.
Top of Casing Elevation	11.0 ft. MSL minimum.

Monitor Wells, Deep

Number	1 (Replacement for 14-D).
Diameter	2 in.
Screened Interval	5 ft. at top of Plaquemine Aquifer.
Depth	90 to 120 ft. including 2 ft. silt trap below screen.
Construction	Schedule 40 PVC, flush jointed, carbon steel protective casing; 6 ft. X 6 ft. concrete pad; dedicated bailer.
Top of Casing Elevation	11.0 ft. MSL minimum.

3.8 Sampling

Frequency	Quarterly for 1st year, semi-annually for next four years, annually for next 25 years.

Analytical Slate (shallow wells)

1st Quarter	Priority pollutant organics (shown in Table 3) plus organics shown in Table 4 - single samples. Monitoring parameters listed in Table 5 - triplicate samples in upgradient wells, single samples in downgradient wells.

TABLE 3

Priority Pollutants

Volatiles
- acrolein
- acrylonitrile
- benzene
- bis (chloromethyl) ether
- bromoform
- carbon tetrachloride
- chlorobenzene
- chlorodibromomethane
- chloroethane
- 2-chloroethylvinyl ether
- chloroform
- dichlorobromomethane
- dichlorodifluoromethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,1-dichloroethylene
- 1,2-dichloropropylene
- ethylbenzene
- methyl bromide
- methyl chloride
- methylene chloride
- 1,1,2,2-tetrachloroethane
- tetrachloroethylene
- toluene
- 1,2-trans-dichloroethylene
- 1,1,1-trichloroethane
- 1,1,2-trichloroethane
- trichloroethylene
- trichlorofluoromethane
- vinyl chloride

Acid Compounds
- 2-chlorophenol
- 2,4-dichlorophenol
- 2,4-dimethylphenol
- 4,6-dinitro-o-cresol
- 2,4-dinitrophenol
- 2-nitrophenol
- 4-nitrophenol
- p-chloro-m-cresol
- pentachlorophenol
- phenol
- 2,4,6-trichlorophenol

Base/Neutral
- acenaphthene
- acenaphthylene
- anthracene
- benzidine
- benzo(a)anthracene
- benzo(a)pyrene
- 3,4-benzofluoranthene
- benzo(ghi)perylene
- benzo(k)fluoranthene
- bis(2-chloroethoxy)methane
- bis(2-chloroethyl)ether
- bis(2-chloroisopropyl)ether
- bis(2-ethylhexyl)phthalate
- 4-bromophenyl phenyl ether
- butylbenzyl phthalate
- 2-chloronaphthalene
- 4-chlorophenyl phenyl ether
- chrysene
- dibenzo(a,h)anthracene
- 1,2-dichlorobenzene
- 1,3-dichlorobenzene
- 1,4-dichlorobenzene
- 3,3-dichlorobenzidine
- diethyl phthalate
- dimethyl phthalate
- di-n-butyl phthalate
- 2,4-dinitrotoluene
- 2,6-dinitrotoluene
- di-n-octyl phthalate
- 1,2-diphenylhydrazine (as azobenzene)
- fluoranthene
- fluorene
- hexachlorobenzene
- hexachlorobutadiene
- hexachlorocyclopentadiene
- hexachloroethane
- indeno(1,2,3-cd)pyrene
- isophorone
- naphthalene
- nitrobenzene
- N-nitrosodimethylamine
- N-nitrosodi-n-propylamine
- N-nitrosodiphenylamine
- phenanthrene
- pyrene
- 1,2,4-trichlorobenzene

Pesticides
- aldrin
- -BHC
- -BHC
- -BHC
- -BHC
- chlordane
- 4,4'-DDT
- 4,4'-DDE
- 4,4'-DDD
- dieldrin
- -endosulfan
- -endosulfan
- endosulfan sulfate
- endrin
- endrin aldehyde
- heptachlor
- heptachlor epoxide
- PCB-1242
- PCB-1254
- PCB-1221
- PCB-1232
- PCB-1248
- PCB-1260
- PCB-1016
- toxaphene

TABLE 4

Additional Organic Compounds for
Monitoring at Bayou Sorrel Site
Which are Not Priority Pollutants

Semi-Volatiles

3-(trifluoromethyl) benzeneamine
1,2-benzene dicarboxylic acid

Herbicides/pesticides

atrazine
dicamba
norflurazon

TABLE 5

Monitoring Parameters

Inorganics	Arsenic
	Lead
	Chromium
	Cadmium
	Sulfate
	Chloride
Organics	Phenol (by GC)
	Ethyl benzene
	TOC
Other	pH
	Specific conductance

Note: Water levels will be measured in each well when water quality samples are taken.

2nd, 3rd, & 4th Quarters	Repeat priority pollutant organics fraction (volatile, acid, base-neutral and pesticide) for any well with positive results from previous quarter. Monitoring parameters listed in Table 5 - triplicate samples in upgradient wells, single samples in downgradient wells.
Years 2 - 30	Monitoring parameters listed in Table 5 - single samples.
Years 5, 10, 15, 20, 25 & 30	Priority pollutant organics (shown in Table 3) plus organics shown in Table 4 - single samples. Within 6 weeks, repeat sampling for priority pollutant fraction for any well with positive results from previous event.

Analytical Slate (deep wells)

Years 0, 5, 10, 15, 20, 25 & 30	Priority Pollutants (Table 3) - single samples.

3.9 Water Level Readings

Frequency	Semi-annually for 30 years.
Wells	All shallow and deep.

4. Drawings

No. 1 - Proposed Cap Design, South Area - Plan View
No. 2 - Proposed Cap Design, North Area - Plan View
No. 3 - South Area Temporary Runoff Control - Initial
No. 4 - South Area Temporary Runoff Control - Final
No. 5 - North Area Temporary Runoff Control
No. 6 - Proposed Cap Design Cross Sections
No. 7 - Cap Base Drain and Vent Details, Monitor Well Details
No. 8 - Temporary Runoff Control Details

5. Attachments

Attachment 1. Monitor Well Design
Attachment 2. Monitor Well Sampling Protocol

ATTACHMENT 1

MONITOR WELL DESIGN

ATTACHMENT 1

MONITOR WELL DESIGN
(SPECIFICATIONS)

1. DRILLING AND SOIL SAMPLING. The drilling contractor shall advance a pilot-hole and sample continuously by standard split-spoon or Shelby tube methods to approximately 20 to 40 feet below land surface. Pilot-holes will not be necessary if drilling is done using a hollow-stem auger. Exact depths will be determined in the field by the hydrogeologist. The target monitoring zone is the shallowest sandy or silty lens. Soil samples will be retained in glass jars provided by the Contractor. The Contractor will collect a minimum of one tube of cohesive sediments from each borehole at the direction of the hydrogeologist. Tubes will be sealed at both ends.

2. WELL INSTALLATION. Typical well construction details are shown on Drawing No. 7. Well casing and screen shall consist of 316 stainless steel with threaded and water-tight flush-joints. No lubricants or joint compounds of any kind may be used. Well screen shall consist of Johnson wire-wrap continuous slot screen or equivalent. Screen slot size shall be 0.010-inch. All well casing and screen shall be steam cleaned on site prior to installation unless the well casing and screen arrive pre-cleaned and plastic wrapped.

   After completion of the soil sampling, the pilot-hole will be reamed to a minimum diameter twice that of the well casing. The reamed borehole will be overdrilled sufficiently below the casing to allow for borehole sloughing. Borehole fluids will be circulated a sufficient length of time to remove sand from the mud column.

   Upon retrieval of the reaming bit the well casing will immediately be placed in the borehole to the target depth. If the casing string does not reach the target depth due to sand sloughing, then an attempt can be made to lower the casing string by jetting through the screen. The casing string must be within 0.5 feet of the target depth or the string must be removed from the borehole. The borehole will then be reamed again and the casing reinstalled. No fluid additives are to be introduced without the approval of the hydrogeologist.

If drilling is completed using a hollow-stem auger, the previous two paragraphs are superseded. Casing shall be set through the center of the hollow-stem auger.

After installation of the casing string, the annulus will be sounded. A sand-pack will be installed at the direction of the hydrogeologist. The sand-pack will be placed by tremie methods or by methods approved by the hydrogeologist. The sand shall consist of well-rounded siliceous sand, medium to coarse-grained, with less than 30 percent passing the #60 sieve (U.S. Standard) and containing less than 5 percent silt or clay and no organic material. All sand must be washed and bagged. An acceptable alternative is manufactured glass beads of appropriate nominal diameter.

A bentonite seal will be placed above the sand pack. The bentonite will be in pelletized form and have a minimum thickness of 2 feet. Sufficient time as specified by the manufacturer for the initiation of swelling must be allowed prior to grout placement.

The annular volume above the bentonite seal will be filled with neat cement grout by tremie methods to within 2 feet of land surface. The grout shall consist of Type I Portland cement mixed with no more than 6 gallons of water per bag of cement. Coarse-grit sodium bentonite shall be added as an antishrink additive at no more than 4 percent by weight of the cement.

The cement grout shall be allowed to cure for a minimum of 12 hours before any further work is done on the well.

3. SURFACE COMPLETION. The surface completion of each well shall consist of a formed and poured concrete pad, The pad shall have 4 steel guard posts in the corners. The steel well casing shall have a locking cap with lock. The locks for all wells shall be keyed alike. A key shall be maintained by EPA to allow access to the well at any time.

4. WELL DEVELOPMENT. All wells installed during this effort will be developed by surging and pumping. The Contractor shall provide all tools and equipment necessary to complete the well development.

After the grout seal has cured, well development shall begin within 3 days following the completion of the monitor wells.

Development shall begin with the use of a valve-type surge plunger or by air surging. The surging shall continue for at least 1 hour or as directed by the hydrogeologist. the desired effect is to remove water and fines from the well by the pumping actions.

The surging shall be followed by pumping of the well for at least 1 hour. The pumping technique shall be approved by the hydrogeologist. If the water remains turbid after 1 hour, then pumping shall continue until the turbidity clears.

At the completion of the well development, the well shall be sounded to determine the amount of fines in the well casing. The well shall be bailed to remove all fines from within the well casing.

5. DRILLING RIG DECONTAMINATION. All downhole equipment and tools will be steam cleaned after each boring and well installation. Clean water shall be circulated through the pump and hoses between sites.

6. GEOTECHNICAL LAB TESTING. Geotechnical lab testing will be conducted to characterize soil properties in the screened zone. Grain-sized distribution by sieve analysis will be conducted on soil samples from each screen interval.

7. SLUG TESTING. Slug tests will be conducted in a minimum of 1/3 of the new wells installed. A minimum of five tests will be conducted for each material type determined by grain size analysis, using the Uniform Soil Classification, to be present in screened intervals, providing five different wells have that distinct material type. Tests will be for the purpose of calculating net permeability of the screened intervals. They will be conducted by the head displacement method, measuring head response with recording pressure transducers or using a manually operated, electric water tape and stop watch.

ATTACHMENT 2

MONITOR WELL SAMPLING PROTOCOL

3/18/87

ATTACHMENT 2

MONITOR WELL SAMPLING PROTOCOL

1. Obtain water-level measurements on all onsite and adjacent water bodies, relative to a known benchmark.

2. Measure water levels in all old PVC monitoring wells.

3. Either Teflon or stainless steel dedicated bailers will be used in the monitor wells.

4. This and following steps through number 9 must be followed for each well. Measure water level in the well relative to the top of the casing to an accuracy of at least 0.05 feet. Enter water level in the field log book. Thoroughly wash the tape between wells using non-phosphate detergent solution with distilled, deionized water rinse.

5. Remove at least three casing volumes of water from the well. Measure pH and specific conductance at least once for each volume removed. Continue purge bailing until consecutive readings of pH are within 0.2 units, and until consecutive conductance readings are within 10 percent.

   Record all values in the field log book, along with how many volumes had been bailed at the time of measurement.

6. Wait for the well to recharge to at least 95 percent of its original volume or for 24 hours, whichever is shorter. Record the recharge time and level in the field log book.

7. Bail enough sample from the well to fill all sample containers, including EPA splits for all parameters.

8. Label, tag, and number all sample bottles, and record sample number with its location for each sample, in the field log book, including EPA splits.

9. Replace the well cap.

10. Place samples into coolers for shipment to selected labs, including chain-of-custody forms and sample numbers associated with each lab. Pack ice in sealed plastic bags around the samples (or sealed containers of "Blue Ice" or an equivalent material), and fill the remaining space with packing material. Close coolers, and place two strips of

custody tape on opposite corners of coolers. Team leader shall complete the custody forms and relinquish custody, reporting the air or bus bill number on custody forms for any coolers that must be shipped.

11. The team leader shall call labs that are receiving shipment to alert them of impending sample arrival and to provide shipping information. Ship or carry the coolers to the selected labs.

12. Splits of all samples shall be collected and made available to the onsite EPA observer. If no EPA observer is onsite, splits shall be collected and shipped to the laboratory or laboratories specified by EPA. Chain-of-custody requirements outlined above shall be followed for all split samples.

ADDENDUM B

GROUND WATER STATISTICS PLAN
Bayou Sorrel, Louisiana

Prepared
for
Bayou Sorrel Task Force

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ATTACHMENT A: Regulatory Context and Copies of Federal Register Citations

ATTACHMENT B: Data Base for the Demonstration

ATTACHMENT C: Methods and Examples for Descriptive Statistics and Trend Analysis

ATTACHMENT D: Methods, Tables, and Examples for Dunnet's Procedure

ATTACHMENT E: Methods, Tables and Examples for Non-Parametric Tests: Kruskal-Wallis and Mann-Whitney-Wilcoxon

ADDENDUM B

GROUND WATER STATISTICS PLAN
Bayou Sorrel, Louisiana

1 - INTRODUCTION

The purpose of this addendum is to provide a performance demonstration for the statistical methods to be used during the monitoring program for the Bayou Sorrel site, Louisiana. This addendum describes the statistical procedures and methodology which will be utilized during the post-construction period of ground water monitoring at the Bayou Sorrel site. These statistical procedures have been specifically designed to meet the requirements of the site's geological and hydrological regime and to provide a technically sound and effective ground water monitoring program.

In a previous report, submitted by the Bayou Sorrel Task Force to EPA in January 1987, ERM-Southwest reviewed the statistical methods proposed in EPA's August 20 proposed rulemaking (Notice of Proposed Rulemaking, 51 FR:29812-29814, August 20, 1986, see Attachment A). ERM-Southwest concluded that only one of the proposed methods was suitable for ground water monitoring (the Dunnet's procedure, applicable to normally distributed data). Three other techniques are presented to cover other types of data distributions. All four techniques are demonstrated herein, in accordance with the performance-based demonstration requirement expected to be proposed by EPA sometime this summer.

The statistical procedures which will be used for post-construction monitoring at the Bayou Sorrel site are:

1) Descriptive statistics and trend analysis for individual monitoring parameters, by well;

2) Dunnet's Procedure (for data bases with normal distributions);

3) Kruskal-Wallis and Mann-Whitney-Wilcoxon tests (for data bases with non-normal distributions); and

4) Practical Quantitation Limits (PQLs) (for data bases consisting primarily of below-detection-limit (BDL) values).

These procedures have received approval by EPA and its technical consultants for application to ground water monitoring results at the Bayou Sorrel Site, subject to the demonstration provided herein. Section 2 presents a summary of the available site-specific data base for the site and discusses selection of appropriate parameters and sampling frequency. Attachment B presents the surrogate data base used for demonstration of the statistical procedures listed above. Section 3 provides a summary of the application of the statistical procedures to the surrogate data base, including the sequence procedure that will be used for the Bayou Sorrel site for performance monitoring of the closure. Mathematical details and detailed results of data analysis are presented in Attachments C through E.

2.1 Selection of Parameters

Ideally, the set of parameters selected for detection monitoring purposes in ground water should be confined to a few indicator parameters that are specific to and characteristic of the waste, and which have demonstrated detectability for a reasonable cost. Parameters which are present in the normal background of the site region and which tend to have highly variable concentrations in ground water for the area should be avoided.

The Bayou Sorrel site is located in southern Louisiana, adjacent to the Upper Grand River. The site is also surrounded by swamps and is influenced by several large natural lagoons. These habitats tend to produce surface water and shallow ground water of uncertain quality and variable gradients (both in slope and direction). For instance, shallow ground waters in coastal areas often have high levels of sulfate, chloride, total organic carbon (TOC), specific conductivity (SC) and metals.

Rivers in southern Louisiana, particularly those close to the Lower Mississippi, are notorious for high levels of metals, chlorides, sulfates, radionuclides and certain organics. To further complicate matters, the unconsolidated strata characteristic of deltaic regions - frequently containing high in situ levels of organic matter, sulfates, salts, etc. - have a strong influence on the water quality of monitor wells completed in the permeable and semi-permeable near surface saturated zones.

Because of the highly variable nature of ground water quality in the site region, there are a number of parameters which are not suitable for detection monitoring in the context of site performance monitoring. These include the standard water quality parameters such as pH, SC, TOC, and Total Organic Halogens (TOH), as well as chlorides, sulfates and certain heavy metals. These parameters tend to be indicative of the prevailing water quality of the nearby surface waters, the geochemistry of the deltaic strata and/or the date-of-sampling recharge status of the shallow saturated zones. Consequently, concentrations of such parameters show high "seasonal" variability.

These parameters (pH, TOC, SC, etc.) can be used effectively to track water-body influence on the ground water at the site and should be followed for the purpose of interpreting ground water flow directions and the chemical matrix of the ground water at each sampling event. However, they should not be used for statistical testing in the context of site performance.

Parameters which are specific to the waste at the Bayou Sorrel site and which will be used for monitoring at the site are:

Indicator Parameters - Phenol (by GC), ethylbenzene, arsenic (As), cadmium (Cd), chromium (Cr) and lead (Pb). These parameters will be subject to statistical testing.

Parameters which are not specific to the waste at the Bayou Sorrel site and which will be used in the future only for monitoring overall water quality and surface water influence are:

Water Quality Parameters - TOC, sulfate (SO_4), chloride (Cl), pH and SC. These parameters will not be subject to statistical testing. However, the data will be tracked using trend analysis (plots of time (x-axis) versus concentration (y-axis)) and will be evaluated annually for each well.

2.2 Sampling Frequency

2.2.1 First Year After Completion of Construction

All wells will be sampled quarterly during the first year. Sampling will include measurements of water levels, indicator and water quality parameters, and priority pollutants. (However, for the 2nd through 4th quarters, only wells with positive results in the 1st quarter will be reanalyzed for priority pollutants).

The North Area closure monitoring system will consist of thirteen wells, including two background wells. The background wells will each be sampled in triplicate to produce a total background data pool of n=24. The triplicates will consist of individual samples taken in the field over a period of one week (each after purging) and will not be laboratory split replicates. Because of the large number of downgradient wells to be installed (11) and because of the lack of a definable upgradient direction, the downgradient wells will be sampled without replication and will be tested in clusters of four wells against the background data set. Any outliers within the well field will be identified using a software package (STATGRAPHICS or its equivalent) which generates Box and Whisker plots (Section 3). Any identified outliers will be tested individually using the appropriate methods for single point comparisons to ensure that any statistically significant excursions are not missed.

The South Area closure monitoring system will consist of 29 wells, including two upgradient wells. The upgradient wells

will be sampled quarterly in triplicate (see above) for the first year to create a background data pool of n = 24. The downgradient wells will be sampled quarterly without replication for the first year, as described above for the North Area.

2.2.2 Years 2 Through 5

For Year 2 through Year 5 after construction, all wells will be sampled annually for indicator and water quality parameters only (see Section 2.1). Downgradient and upgradient (background) wells will be sampled without replication. Concentrations of indicator parameters in downgradient wells will be tested in clusters of four wells against the background data pools (n = 24) generated during the first year of quarterly sampling. Each well will be tracked individually using plots of time versus concentration for all of the monitoring parameters (i.e., individual well "trend charts" will be kept).

On a semi-annual basis, all wells will be sampled for water level, specific conductivity and pH (field measurements) only. These data will be plotted on individual well trend charts. In Year 5, all wells will be sampled for priority pollutants, with repeat sampling within six weeks after receipt of analytical results for any priority pollutant fraction in any well with positive results from the original Year 5 sample.

2.2.3 Years 6 Through 30

All wells will be sampled without replication annually for all indicator and water quality parameters, and water level measurements will be taken. On a semi-annual basis, all wells will be sampled for water level, specific conductivity and pH (field measurements) only. These data will be plotted on individual well trend charts. Downgradient wells will be statistically tested annually in clusters of four versus the appropriate background data pool for indicator parameters only. All individual well trend charts will be updated. In Years 10, 15, 20, 25 and 30, all wells will be sampled for priority pollutants, with resampling within six weeks after receipt of analytical results for any priority pollutant fractions for wells with positive results from the previous sampling event.

3.1 Basic Data Management: Descriptive Statistics and Trend Analysis

The results of chemical analyses of ground water samples for all parameters monitored at the Bayou Sorrel site will be entered into a Data Management Program (DMP) prior to any statistical testing related to site performance. The basic elements of the DMP will include:

1. Computerization of data into LOTUS 1-2-3 (or other appropriate data base management software) files. Input will include dates of sample, well location codes, units of measure, detection limits, sampling method, sampling personnel/company and analytical laboratory ID.

2. Restructuring of the computerized data base for each monitoring parameter (if necessary) to import from data management files to STATGRAPHICS (or similar) statistical software package.

3. After completion of the first year of quarterly samples, application of descriptive statistics to the data bases for each parameter (for individual wells and the well field as a whole) to determine data distribution (normal or non-normal), including at a minimum:

   a. STATGRAPHICS Code Book Procedure, illustrated in Figure 3-1, including graphs of error bars for each well (See also Attachment C, Section C-2).

   b. Frequency histograms (see Figures B-1, B-2 and B-3, Attachment B).

   c. Multiple Box & Whisker Plots showing medians, first and second quartiles and outliers (Figure 3-2).

4. Performance of trend analyses using simple linear regression (Figure 3-3) for each well for each parameter (Attachment C, Section C-3).

5. Determination of the distribution of the data base (normal, non-normal or BDL) for each parameter to be statistically tested for location differences (background or downgradient).

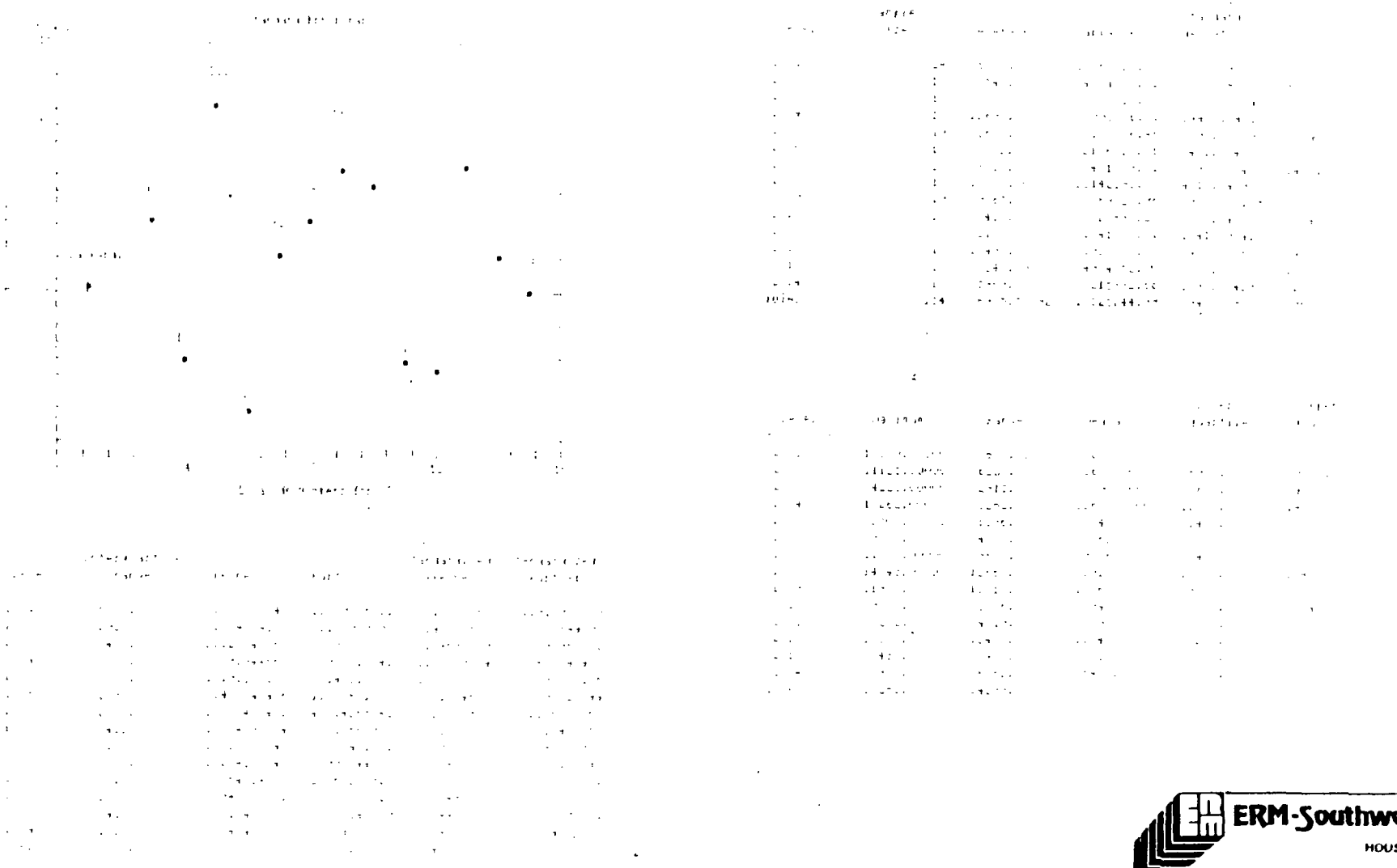

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FIGURE 3-1
EXAMPLE OF STATGRAPHICS® CODE BOOK
PROCEDURE FOR TOC
BAYOU SORREL STATISTICS DEMONSTRATION

W O NO	
20-08	4/28/87

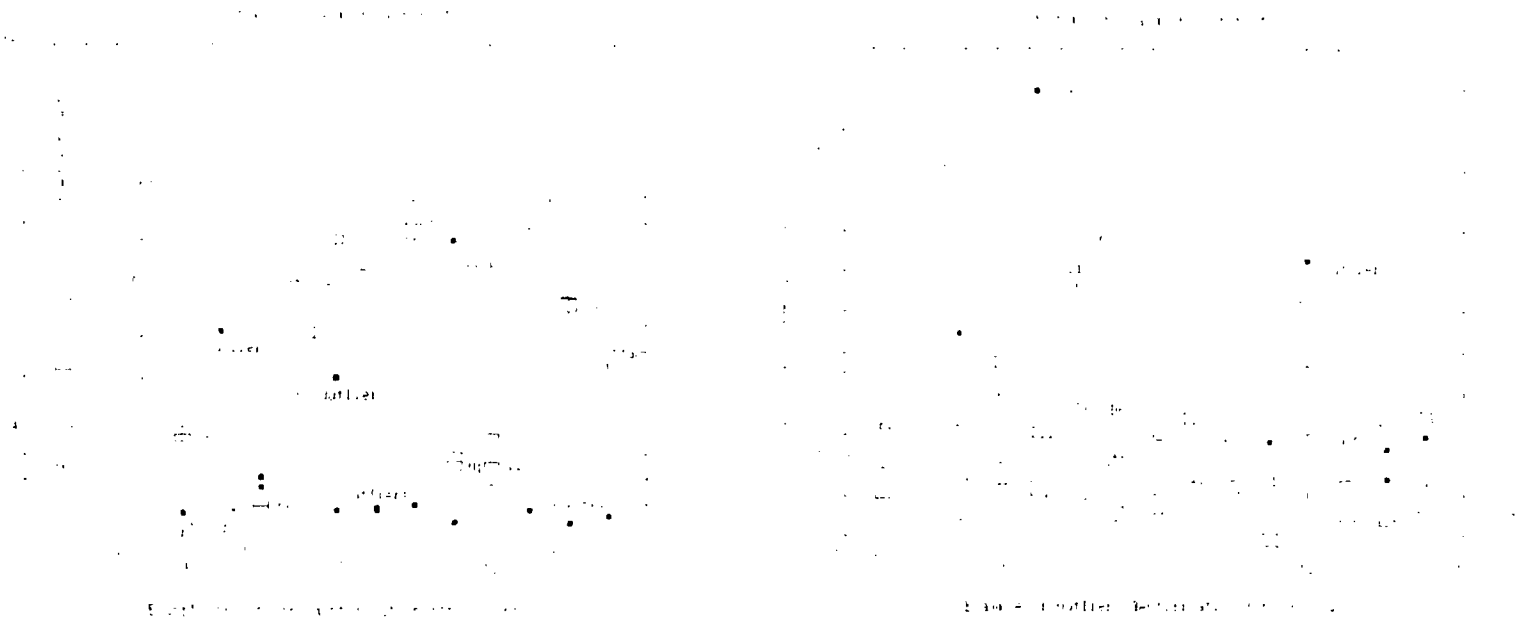

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FIGURE 3-2
OUTLIER IDENTIFICATION USING
BOX & WHISKER PLOTS
BAYOU SORREL STATISTICS DEMONSTRATION

W O NO	20-08	4/28/87

Simple Regression of AvgSC SELECT LocaCode EQ 3 on Timeline

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	6995.4	756.1	9.2519	7.5881E-4
Slope	3.7595	0.9553	3.9354	0.017026

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio
Model	4613908.0	1	4613908.0	15.5
Error	1191662.8	4	297915.7	
Total (Corr.)	5805570.8	5		

Correlation Coefficient = 0.89148
Stnd. Error of Est. = 545.82

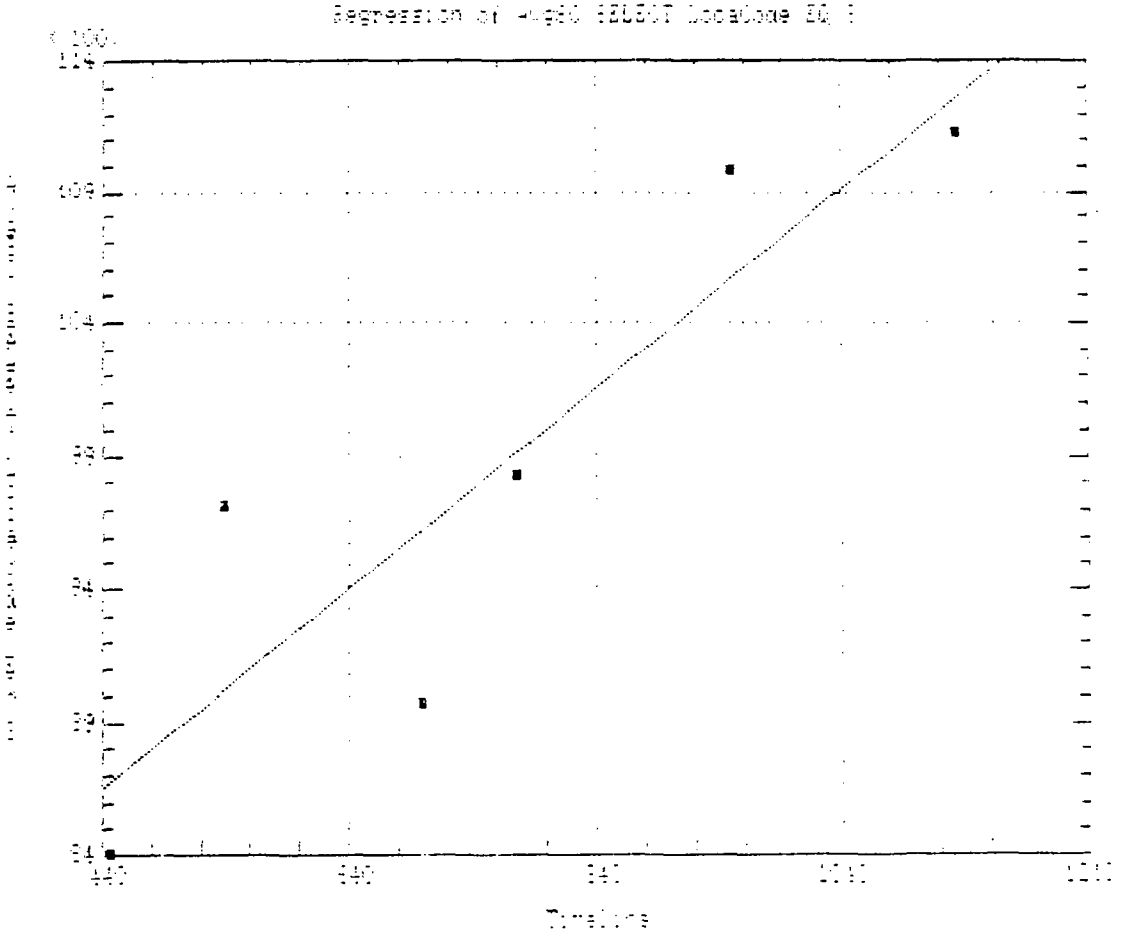

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FIGURE 3-3
EXAMPLE OF STATGRAPHICS®
SIMPLE LINEAR REGRESSION PROCEDURE
BAYOU SORREL STATISTICS DEMONSTRATION

4/28/87

W.O. NO. 20-08

6. Performance of significance testing for differences in background and downgradient water quality for As, Cd, Cr, Pb, Phenol and ethylbenzene using the method appropriate to the distribution of each parameter.

The major elements of the DMP are discussed in the following subsections.

3.1.1 Descriptive Statistics

Statistical comparisons of data bases which have normal distribution should preferentially be done using parametric techniques. Dunnet's procedure and the various forms of the t-Test are two examples of parametric tests of significant differences in means.

The EPA suggested criteria for "normal distribution" is that the coefficient of variance (CV) be less than 1.0, calculated as:

$$CV = (\text{std. dev.})/\text{mean}$$

Although this is a very crude measure of "normality", it is capable of detecting grossly non-normal distributions. However, the distribution of all data bases should be verified by other more stringent methods, such as graphic representation of the frequency distribution (e.g., frequency histograms) and application of tests for skewness and kurtosis. These tests will be performed using STATGRAPHICS subroutines as illustrated in Attachment C, Sections C-1 and C-2, and Section 3, Figures 3-1 and 3-2.

Tests to determine the data distribution for each parameter will be performed on the cumulative data base that is generated for the entire well field at each of the two areas, as well as for individual wells. Data distributions will be determined for all monitoring parameters before application of any other statistical procedures. Data management and statistical analyses will be performed for every annual ground water monitoring report.

3.1.2 Trend Analysis

After Descriptive Statistics subroutines have been applied, data for each parameter in each well will be plotted versus time and a simple linear regression will be performed using another

STATGRAPHICS subroutine (See Attachment C, Section C-3). The regression algorithm has the form

$$y = ax + b$$

where "y" is the concentration of the parameter, "a" is the slope of the regressed line, "x" is time (in days since the start of the monitoring program), and "b" is the y-intercept of the regressed line. The subroutine provides correlation coefficients, ANOVA results with F-ratios, probability levels for the slope and intercept, and standard error of the estimate, in addition to a plot of the regression line and data points, as illustrated in Figure 3-3.

The significance of the slope of the regressions for each well will be evaluated, beginning in Year 5, using one or both of the following statistics:

1) If the T-value of the slope is insignificant at the 0.05 probability level, the well will be reported to have a significant trend. In Figure 3-3, for example, the probability level for the T-value (3.9354) is 0.017026, which is less than 0.005; therefore the slope of the regression for well D7 is significantly greater than zero.

2) If the F-ratio for the ANOVA is significant at the 0.05 level, the well will be reported to have a significant trend. (The null hypothesis for the ANOVA is that the slope of the regression is equal to zero). Tables for the critical values of F are presented in Attachment C, Section C-3. In Figure 3-3, the F-ratio (15.5) is greater than F-critical at the = 0.05 level (7.71); therefore the trend for D7 is significant.

For all parameters except pH, only positive trends (slopes greater than zero) will be tested for significance; pH will be tested for both positive and negative trends.

3.2 Parametric Methods

A number of parametric methods are available for application to normally distributed data. These include the Student's t-Test and the CABF (Cochran's Approximation to the Behrens-Fisher t-Test), both of which are one-way comparisons that have been shown to have serious limitations when applied to data generated in ground water monitoring programs. Many of these limitations, including seasonality and replication, can be eliminated or accounted for by use of multi-way comparisons, such as Dunnet's procedure and one-way or two-way ANOVAs (with or without replication) procedures (ANOVA = Analysis of Variance).

TABLE 3-1

DUNNET'S PROCEDURE: Parameteric Simultaneous Comparison of Downgradient Wells to Background Data

Summary of Mathematics

w	=	total no. of downgradient wells
Nw	=	no. observations per well
x	=	value of observation for individual well
Xw	=	mean of the x-values for individual wells
Vw	=	variance of values for individual wells
	=	(SUM(x-Xw))/(Nw-1)
Sw	=	standard deviation = SQRT of Vw
SSw	=	sum of squares of x-values for each w
Sx	=	sum of x-values
SxS	=	Sx squared

GENERAL CASE (Equal or Unequal sample size)

Vc	=	common variance = (SUM((SxS)/Nw)))/d.f.
Sc	=	common standard deviation = SQRT of Vc
d.f.	=	SUM(Nw) - (w + 1)
Tm	=	test statistic calculated as

Tm = (Xm - Xb)/(Sc*(SQRT(1/Nb + 1/Nm)))

where Nb = no. of obsrv. for background Well B

Nm = no. of obsrv. for monitoring Well M

and Xm = mean of obsrv. for monitoring Well M

Xb = mean of obsrv. for background Well B

Tm = critical point (from Tables D-2(a, b, c & d) Attachment D)

Compare Tm to Tc; if Tm>Tc, a statistically significant difference is indicated.

Note: if Xm<Xb for any parameter (except pH), no testing is required.

The advantage of Dunnet's procedure is that it is relatively simple to perform (see Attachment D) and can be used to compare multiple wells with unequal sample sizes. Tables of critical values are available for one- and two-sided comparisons of up to nine downgradient wells. The method provides one of the few truly simultaneous comparisons of multiple "treatment groups" (downgradient wells) to a "control group" (upgradient well) available in the literature. The comparison is made by calculating a common standard deviation and variance for the entire well field. The mathematics of the method are summarized in Table 3-1.

In the context of the Bayou Sorrel site, the primary disadvantage of Dunnet's procedure is that it may not lend itself to analysis of very large data bases (for instance, where both the number of wells (w) and the number of observations per well (Nx) are large) and/or to data with very large variances (Vx). The total number of individual downgradient wells or well clusters cannot, in fact, exceed nine because tables for critical Tc values have not been developed for larger data fields. However, because of the proposed clustering of the downgradient unreplicated well samples, the resulting matrix is not a problem, as demonstrated below and in Attachment D.

ERM-Southwest has developed a LOTUS 1-2-3 program to run Dunnet's procedure. Examples of Dunnet's Procedure using clustered well data for hypothetical SC values are provided in Attachment D.

As discussed in Attachment B, the available hypothetical data base is large enough to construct a hypothetical well field only for the North Area. However, Dunnet's procedure will also work very well with the seven 4-well clusters that will be generated for the South Area.

3.3 Non-parametric Methods

Non-parametric techniques are used for significance testing of non-normal data bases. A number of techniques are widely recognized and readily available in the current literature, including the Kruskal-Wallis test, the Simultaneous Test Procedure (STP - a variation of the Mann-Whitney U-test developed for more than two groups of data), the Mann-Whitney-Wilcoxon test, and Friedman's Method for Randomized Blocks (also known as Friedman's Two-Way Analysis by ranks, a non-parametric analogue of a two-way ANOVA). All of these are rank/sum tests which allow "simultaneous" comparison of two or

more wells. Kruskal-Wallis, Mann-Whitney-Wilcoxon and Friedman's procedures are readily available in PC software. Except for Friedman's, these procedures allow unequal sample sizes.

In the case of the Bayou Sorrel well field, clusters of two upgradient wells will be tested against multiple clusters of four downgradient wells using Kruskal-Wallis and Mann-Whitney-Wilcoxon procedures in sequence, as discussed below. Examples of both methods are provided in Attachment E.

3.3.1 Kruskal-Wallis Test

As mentioned above, the Kruskal-Wallis test is a non-parametric alternative for single-classification ANOVA techniques (such as the t-test, which is a special case of the single-classification ANOVA and compares only two sets of data - or wells - at a time). The Kruskal-Wallis test is recommended for the general case with "a" samples and n_i variates per sample. The test can be used for comparison of samples with varying sample sizes.

This test is generally used for testing differences between more than two groups (i.e., two wells) and will be used as a "first cut" test to determine if the well system as a whole has any significant differences as a function of well location. In accordance with recommended procedures for the test, the data base for each group will consist of mean values for each date of sample (if samples are replicated) and will include at least five sample dates worth of data (e.g. four quarters of "background data" for downgradient wells plus the first semi-annual sample in Year 2). NOTE: Replicate values can be used, but may result in an inordinate number of "ties" for ranks. After Year 2, the procedure will be run using only the Year 1 background data base and the three downgradient 4-well clusters for each annual sample of indicator parameters.

To summarize the mathematics of Kruskal-Wallis, the test is performed by first ranking all the variates from smallest to largest, ignoring the division into sample groups (see Attachment E, Figure E-1). For ties in ranks, the average of the ranks occupied by the tied values is calculated, as shown in Attachment E, Figure E-1. Next, the original data table is reconstituted but the value for the original variate is replaced by its rank (or average rank, as the case may be) and an H-statistic is calculated (Attachment E, see Step 4, Figure E-1) and corrected for ties (as shown in Step 5).

A STATGRAPHICS subroutine will be used to perform the Kruskal-Wallis test for the Bayou Sorrel site (Attachment E, Section E-2). The program calculates a "test statistic" and computes a precise significance level for rejection of the null hypothesis. For example, in Figure 3-4, values are compared as a function of cluster grouping (variable name = "ClstCode"), well location (variable name = "LocaCode") and date of sample (variable name = "TimeLine"). The results indicate differences in SC that are significant at the 0.0000009 probability level for cluster grouping, and at the 0.0000000008 probability level for well location. Date of sample was not significant over the time period tested.

The Kruskal-Wallis procedure was run for the hypothetical SC and TOC data bases (clustered wells) for this demonstration. The results of these runs are provided in Attachment E, Section E-2. Any runs for which the significance level is less than 0.05 would indicate a statistical significant difference at the 0.05 level.

3.3.2 Mann-Whitney-Wilcoxon Test

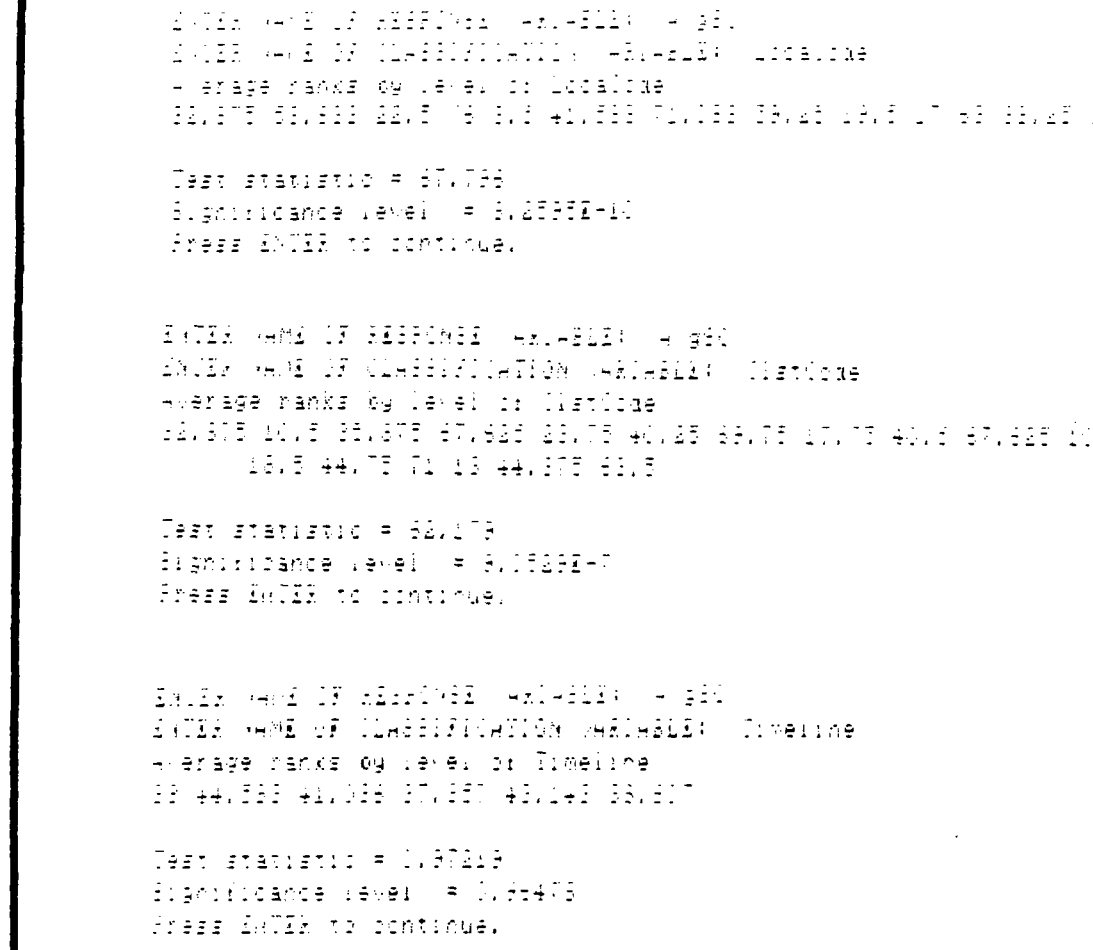
The Mann-Whitney U-test and the Wilcoxon two-sample test are two non-parametric tests which yield the same statistic (U_s) and give the same result. If the results of the Kruskal-Wallis analysis indicate significant location effects at the 95% confidence level (0.05 significance level), a STATGRAPHICS subroutine called Mann- Whitney-Wilcoxon will be used to compare individual wells against the pooled background.

The null hypothesis for the Mann-Whitney-Wilcoxon is that the two samples being tested come from populations having the same distribution. An example problem, including all formulas necessary for performing the test, is given in Attachment E, Figure E-5. Examples of the STATGRAPHICS subroutine results are provided in Attachment E, Section E-3.

3.4 Methods for Special Distributions

Ground water data frequently contain parameters whose distributions are either artificially truncated (e.g., by detection limits) or which are extremely skewed toward one or the other end of the concentration range. Such data bases cannot be legitimately analyzed using standard parametric or non-parametric methods.

Two alternate techniques have been suggested by various reviewers of the proposed EPA rulemaking for data where background values are below detection limits (BDL). These are



NOTE: If the significance level for the Test Statistic is <0.05, a statistically significant difference is indicated. In this example, well location (LocaCode) and cluster grouping (ClstCode) are highly significant, whereas date of sample (Timeline) is not.

ERM-Southwest, inc.
HOUSTON, TEXAS

FIGURE 3-4
EXAMPLE OF KRUSKAL-WALLIS
PROCEDURE FOR UNREPLICATED SC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

7/14/87

W.O. NO. 2008

the "Tolerance Interval Test" (suitable for "rare event" data that tend to follow the Poisson distribution), and a "Critical Limit Test", based on a confidence interval around the theoretical detection limit for each monitored parameter, which provides a cut-off level for acceptable ground water concentrations of a parameter near the detection limit.

The Critical Limit test is conceptually much simpler and more routinely applicable for near-detection-limit data than the Poisson and has been selected for analysis of such data at the

Bayou Sorrel site. Based on EPA's recommendation in the November 13, 1986 Federal Register for "Practical Quantification Limits", the critical limit for parameters whose background data set consists entirely of BDLs will be set at 10 times the detection limit for ground water at the site.

The parameters that are likely to show BDL distributions at the Bayou Sorrel site are phenol and ethylbenzene. These two organics will be analyzed using approved EPA methods. The method detection limits (MDL) and resulting PQLs will be determined based on industry standards for the selected detector(s) at the time monitoring begins. Compliance would be determined by simply comparing the sample results to the PQL for any positive "hits" for these two compounds. If the sample results exceed the PQL (i.e., are greater than 10 times higher than the MDL), a significant difference would be indicated.

ATTACHMENT A

ATTACHMENT A-1: Regulatory Context

ATTACHMENT A-2: Copies of Federal Register Citations and EPA Description of Statistical Procedures for the Proposed Rulemaking

ATTACHMENT A-1

Regulatory Context

ATTACHMENT A-1
REGULATORY CONTEXT

1 - Regulatory Background

EPA is considering revision of regulations concerning the statistical procedures applied to ground water requirements (U.S. EPA, 1986, Attachment A-2). EPA is considering changes primarily because the currently recommended procedures may indicate contamination when none is present (the so called Type I error or "false positive"). Specific concerns include:

- Current method is not appropriate for the replicate sampling method.
- Current method does not adequately consider the number of comparisons that must be made.
- Current method does not control for seasonal variation.

These shortcomings could result in further characterization of a ground water monitoring system when it may not be justified (e.g. collect more water samples and analyze them for additional constituents).

A second reason EPA is considering changes is that there may be instances where actual contamination is not detected (Type II errors or "false negatives"). This may occur because the upgradient well or background data set is calculated by combining observations with very high variance rather than comparing up and down gradient concentrations each quarter.

Consequently, EPA is considering changing BOTH the statistical procedure and the sampling and analytical (QA/QC) requirements and has proposed the following actions:

- A more complete characterization of the ground water and hydrogeological conditions at the site.
- A performance standard for statistical procedures and sampling methods.
- Procedures which have a low probability of Type I and Type II errors.
- Performance demonstration that a procedure is appropriate for the conditions of the site.

EPA is considering a performance standard that would include the following requirements:

1. The procedure(s) and sampling requirements must be protective of human health and the environment.

2. The procedures must determine the statistical distribution of each parameter or constituent selected for analysis

   a. The procedure must be appropriate for the distribution.

   b. If individual parameters have different distributions, more than one procedure needs to be demonstrated.

3. The procedure(s) should have a low probability of indicating contamination when it is not present and of failing to detect contamination that is actually there. Different numbers of sample points should be considered for different constituents or procedures.

4. The procedures should be appropriate for the hydrogeologic setting and the physical layout of the ground water monitoring system.

5. The procedures should describe how observations below the detection limit will be handled.

6. The procedures should consider, or control for, seasonal and spatial variability and temporal correlation.

2 - EPA Recommended Statistical Procedures

EPA is specifically considering three statistical procedures, one parametric, one non-parametric and one "critical limit". These three procedures correspond to data bases with normal, non-normal and below-detection-limit data distributions, respectively. The Type I error (probability of a false positive) will be set at 0.01 or 0.05.

The parametric test under consideration for normally distributed data bases is the Dunnet's Test, a form of the F-test. The non-parametric test suggested for non-normal data bases is the Steel's test, a form of the Wilcoxon test. Both of these tests are designed for simultaneous comparisons of multiple down gradient wells against a single background data set.

For parameters which have background values at or barely above detection limits (a frequent condition where one or more specific organics have been selected as indicator parameter(s)), EPA is suggesting the use of control charts to determine a "critical concentration" limit. This limit is generated by a tolerance or confidence interval around the detection limit concentration. This creates an "upper control limit" which is compared to the concentration found in a downgradient well on a "go-no go" basis to determine statistical significance of any value above the detection limit.

EPA Recommended Sampling Requirements

EPA has suggested the following sampling frequencies to "better characterize the distribution of ground water constituents at a facility":

- Samples should be taken daily for approximately one week each month for an (undefined) initial period.

- The number and frequency of samples may be reduced once the owner or operator has "characterized the facility".

- Comparisons between upgradient and downgradient wells should be conducted at least twice per year.

- During each of these sampling periods, the owner or operator must "take daily samples for as long as it takes to achieve a reasonable probability of detecting actual contamination".

- Replicate samples should be used only as a quality control measure and not as the source for statistical variance used in significance testing procedures.

- At least two upgradient wells are required.

Demonstrations of Alternative Procedures

EPA is considering allowing demonstrations of alternate procedures to be used for detecting ground water contamination. Selection of a procedure other than those recommended by EPA would require a demonstration that the alternate procedure(s) are appropriate. Currently, such a demonstration would include the following in addition to meeting the performance standard:

1. References indicating that the procedure is documented in statistical or mathematical literature.

2. An explicit example showing calculations using data from the facility.

3. A list of all data from the facility.

4. Quality control measures used at the facility.

Reference: U.S. EPA, 1986. Hazardous Waste Land Disposal Facilities; Statistical Procedures for Detecting Ground-Water Contamination. 51 FR 29812-29814. August 20, 1986.

ATTACHMENT A-2

Copies of Federal Register Citations and
EPA's Description of Statistical Procedures
for the Proposed Rulemaking

- 51 FR 161:29812 (August 20, 1986) "Hazardous Waste Land Disposal Facilities: Statistical Procedures for Detecting Ground Water Contamination"
- Description of Statistical Procedure for Detection of Ground Water Contamination at Hazardous Waste Land Disposal Facilities
- 50 FR 219:46906 (November 13, 1985) "Method Detection Limits and Practical Quantitation Levels"

- 51 FR 161:29812 (August 20, 1986)
  "Hazardous Waste Land Disposal Facilities: Satistical Procedures for Detecting Ground Water Contamination"

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 264 and 265

[SW-FRL-3045-7]

Hazardous Waste Land Disposal Facilities: Statistical Procedures for Detecting Ground-Water Contamination

AGENCY: Environment Protection Agency.

ACTION: Advance notice of proposed rulemaking.

SUMMARY: EPA promulgated regulations for detecting contamination of ground water at hazardous waste land disposal facilities under the Resource Conservation and Recovery Act of 1976 (RCRA). The methods in the regulations for detecting contamination have been criticized by industry for a number of technical reasons. EPA is considering revision of the regulations. Today EPA is providing advance notice of this proposed rulemaking and requests comments from the public to assist in the regulatory development process.

DATE: EPA will accept comments on this advance notice of proposed rulemaking until October 6, 1986.

ADDRESSES: Send comments to: Docket Clerk, Office of Solid Waste (WH-562), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460. Comments should be identified as follows: "Docket No. F-86-GWSA-FFFFF, Ground-water Monitoring Statistics."

The public docket for this advance notice of proposed rulemaking is located at EPA RCRA Docket (Sub-basement), 401 M Street, SW., Washington, DC 20460. The docket is open from 9:30 to 3:30 Monday through Friday, except for Federal holidays. Copies of USEPA "Description of Statistical Procedures for Detection of Ground-Water Contamination at Hazardous Waste Land Disposal Facilities" are available for *viewing only* in the RCRA Docket room. The public must make an appointment to review docket materials. Call Mia Zmud at (202) 475-9327 or Kate Blow at (202) 382-4675 for appointments. The public may copy a maximum of 50 pages of material from any one regulatory docket at no cost. Additional copies cost $.20/page.

FOR FURTHER INFORMATION CONTACT: For general information contact: RCRA/Superfund Hotline, Office of Solid Waste (WH-563C), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460, telephone (800) 424-9346, or (202) 382-3000. For [illegible]

SUPPLEMENTARY INFORMATION:

I. Background

Subtitle C of the Resource Conservation and Recovery Act of 1976 (RCRA) creates a comprehensive [illegible] requires owners and operators of facilities that treat, store, or dispose of hazardous waste to comply with standards established by EPA that are "necessary to protect human health and the environment." Section 3005 provides for implementation of these standards under permits issued to owners and operators by EPA or authorized States. Section 3005 also provides that owners and operators of existing facilities that comply with applicable notice requirements may operate until a permit is issued or denied. This statutory authorization to operate prior to permit determination is commonly known as "interim status." Owners and operators of interim status facilities also must comply with standards set under Section 3004.

EPA promulgated standards for interim status facilities in 1980 (45 FR 33154 (May 19, 1980)), codified in 40 CFR Part 265, Subpart F, and permitted facilities in 1982 (47 FR 32274 (July 26, 1982)), codified in 40 CFR Part 264, Subpart F. Both sets of standards establish programs for protecting ground water from releases of hazardous wastes from treatment, storage, and disposal units. Both programs require owners and operators to sample ground water at specified intervals and use a statistical procedure to determine whether or not hazardous wastes or constituents from the facility are contaminating ground water. As explained in more detail below, the sampling and statistical procedures EPA promulgated in 1980 and 1982 have generated criticism. EPA is today providing advance notice of its intent to consider proposing changes to these rules and solicits public comment on a number of issues it will consider in formulating proposed rules.

II. Existing Regulations in 40 CFR Parts 265 and 264

The ground-water regulations for interim status facilities require that the upgradient well(s) be sampled quarterly for one year (§ 265.92 (c) (1) and (2)). The regulations specify a set of indicator parameters for which concentrations must be measured. An initial background concentration for each parameter must be determined by measuring at least four replicates [illegible] hazardous waste units and [illegible] (§ 265.92(c)(2)). After the first year, the owner or operator must compare concentrations measured at downgradient wells with these background concentrations. The owner [illegible] mean and variance of the concentration of each parameter based on at least four replicate measurements for each sample for each downgradient well. The owner or operator must compare the mean concentration at each downgradient well with the initial background concentration mean using the Student's t-test at the .01 significance level to determine statistically significant increases over background (§ 265.93(b)). If these comparisons indicate contamination, the owner or operator must obtain additional samples and determine if the significant increase was due to laboratory error (§ 265.93(c)(2)). If the significant difference is confirmed, the owner or operator must take measures to determine the rate and extent of the contamination (§ 265.93 (d)(4) (i) and (ii)).

The standards for permitted facilities that have not detected ground-water contamination prior to permit issuance require the owner or operator to establish a detection monitoring program. Under this program, the owner or operator must determine background ground-water quality for a site specific set of parameters or constituents by taking a minimum of one sample from each well and a minimum of four samples from the system used to determine background ground-water quality each time the system is sampled (§ 264.97(g)(4)). At least semi-annually (§ 264.98(d)), the owner or operator must take at least four replicate measures of a sample at each downgradient well and determine if the mean of the constituent differs from the mean upgradient using Cochran's Approximation to the Behren's-Fisher Student's t-test (CABF) at the .05 significance level. The owner or operator must repeat the procedure with new samples if this test indicates significance (§ 264.97(h)(1)(i)). The owner or operator may also use an equivalent statistical procedure specified by the Regional Administrator to determine if a statistically significant change has occurred (§ 264.97(h)(1)(ii)).

If a statistically significant increase is found, the owner or operator must sample all monitoring wells to determine the concentration of constituents listed in Appendix VIII of section 261 (see 51 FR 5561 (February 14, 1986) for further

information on Appendix VIII). The owner or operator must also submit an application for a permit modification to establish a compliance monitoring program to monitor the levels of all constituents found in the ground water (§ 264.98(h)). Under this program, the Regional Administrator will specify in the facility permit the ground-water protection standard (§ 264.99(a)). This ground-water protection standard shall include a list of hazardous constituents identified under § 264.93 and concentration limits established under § 264.94. The owner or operator must determine the concentration of hazardous constituents in ground water at each downgradient monitoring well at least quarterly (§ 264.99(d)).

If the owner or operator determines that the ground-water protection standard is being exceeded by showing that a statistically significant increase over the concentration limits for any hazardous constituents has occurred (§ 264.99(h)), he must submit an application for a permit modification to establish a corrective action program (§ 264.99(i)).

III. Changes Under Consideration

EPA is considering changes in the current regulations because the procedures may indicate contamination when it is not present. Concerns have been raised that the statistical procedure in the current regulations is not appropriate for the replicate sampling method, does not adequately consider the number of comparisons that must be made, and does not control for seasonal variation. Specifically, the concerns are that these procedures could result in an owner or operator having to further characterize the site when it may not be necessary. In addition to collecting additional ground-water samples and analyzing for additional constituents, an owner or operator of a permitted facility would have to apply for a permit modification which EPA must review. A second reason EPA is considering changes is that there may be instances where actual contamination goes undetected. This may occur because the mean concentration at the upgradient well is calculated by combining observations which may vary widely over the four quarters rather than comparing upgradient and downgradient

[illegible] statistical procedure and the sampling and analytic (quality control/quality assurance) requirements in both sets of regulations for the analysis of groundwater [illegible]. EPA plans to [illegible]

completely characterize the ground water and hydrogeology at the facility. EPA also intends to include a performance standard in the regulations which the statistical procedures and the sampling methods must meet. Such procedures would have a low probability of missing contamination that exists at a facility and a low probability of indicating contamination when it is not present. The facility owner or operator would have to demonstrate that a procedure is appropriate for the conditions at that facility provided that it meets the performance standard outlined below. Specific procedures EPA is considering are identified below.

EPA recognizes that the selection of appropriate monitoring parameters is also important and has a separate effort devoted to this issue (51 FR 5561 (February 14, 1986).

A. Performance Standard

EPA is considering a performance standard that would include the following requirements:

1. The procedure(s) and sampling requirements must be protective of human health and the environment.

2. The owner or operator must determine the statistical distribution of each parameter or constitutent listed in the facility permit. The statistical procedure(s) must be appropriate for the distribution. The owner or operator could demonstrate that the distributions of constitutents differ and, thus, more than one procedure is needed at a facility.

3. The procedure(s) should have a low probability of indicating contamination when it is not present and of failing to detect contamination that is actually there. The owner or operator should consider different numbers of sample points for different constituents or procedures.

4. The procedure(s) should be appropriate for the hydrogeologic setting and the physical layout of the ground-water monitoring system.

5. The owner or operator should describe how observations below the detection limit will be handled in the procedure(s).

6. The owner or operator should consider, or control for, seasonal and [illegible] procedure(s).

EPA is evaluating the following statistical procedures and sampling requirements and believes they will meet the performance standard it may [illegible]

B. Statistical Procedures

1. Comparisons of individual upgradient wells and downgradient wells using a form of the F-test (parametric) or the Wilcoxon test (non-parametric). The specific forms of these tests EPA is considering are Dunnett's test (parametric) and Steel's test (non-parametric). A publication "Description of Tests for Detecting Ground-Water Contamination at Land Disposal Facilities" describing these procedures is available for viewing in the Docket for this rulemaking.

2. Comparisons of concentrations at downgradient wells to expected concentrations using control charts. This technique is also described in the publication named above.

3. Set the Type I error (probability of indicating contamination when it is not present) level at 0.01 or 0.05.

C. Sampling Requirements

1. Initially, samples should be taken daily for approximately a week each month in order to better characterize the distribution of ground-water constitutents at a facility. The number and frequency of samples may be reduced once the owner or operator has characterized the facility.

2. Conduct comparisons between upgradient and downgradient wells at least two times per year. During each of these sampling periods, the owner or operator must take daily samples for as long as it takes to achieve a reasonable probability of detecting actual contamination.

3. Use replicate samples only as a quality control measure, rather than as a means to gather additional samples to improve the ability of a statistical procedure to detect contamination.

4. Require at least two upgradient wells.

D. Quality Control

EPA plans to require that the owner or operator implement a quality control program for taking ground-water samples and determining concentrations of constituents therein.

E. Demonstrations That Alternate Procedure is More Appropriate

EPA is considering allowing the owner or operator to select the procedure for detecting [illegible] would require a demonstration that the other procedure is appropriate. Currently, EPA thinks this demonstration should include the [illegible]

[illegible]

2. An [illegible] example showing calculations using data from the facility.

3. A list of the data from the facility.

4. Quality control measures used at the facility.

[illegible] implementing. The ground-water monitoring regulations in Part 265 allow owners and operators to select and use variants of the Student's t-test without EPA review and approval. EPA is considering several options for modifying Part 265 to accommodate the more complex statistical and sampling procedures described today. EPA may try to develop more specific standards that owner or operators could implement without EPA review. Alternatively, EPA may make an exception to the Part 265 approach and require the owner or operator to submit a site-specific statistical procedure and sampling plan for review and approval.

IV. Comments From the Public

There are several approaches to determining if a facility is contaminating the ground-water. Two major differences in approach EPA would like to resolve are:

- Comparisons of concentrations at all wells upgradient against all wells downgradient or comparisons of concentrations at each upgradient well against each downgradient well.
- Comparisons at a point in time or over time.

EPA wants to ensure that ground-water contamination is detected as soon as possible after it occurs.

EPA is soliciting information that will help evaluate the ways to approach determining if a facility is contaminating the groundwater, the performance standard, and the specific approach outlined in the previous section. EPA would like any available data that owners or operators may have to evaluate these items. EPA needs to evaluate the following specific questions or issues:

1. How will the procedures perform in actual practice?

2. How [illegible] be to different distributions?

3. Type I error (indicating contamination when it is not present) is closely related to Type II error (missing existing contamination). EPA would like the public to provide available data for EPA to use to determine Type II error [illegible] in section III B [illegible] the sampling program described in section III C.

4. Are there other statistical procedures or sampling requirements that minimize both Type I and Type II errors? EPA would also like to receive data showing the number of Type II errors expected under any alternate statistical procedure or sampling scheme.

5. Are there modelling or measurement techniques that make it possible to determine the flow path of the ground water from an upgradient well to a particular downgradient well, or to several adjacent downgradient wells?

6. Does transforming data to its logarithm or square root improve conformance to assumptions of a statistical procedure or are there appropriate procedures for untransformed data?

7. EPA needs to take steps to protect human health and the environment while the owner or operator is taking samples to characterize the facility. EPA is considering a simple comparison of mean concentrations rather than a statistical procedure during this period. EPA needs information to use to determine if this would have acceptable Type I and Type II error levels.

8. What Type I and Type II error levels result for the recommended procedures when concentrations of constituents are below the detection limit? What error levels would result for other procedures?

9. Groundwater monitoring data may be autocorrelated. EPA needs information on the degree of autocorrelation at facilities and appropriate corrections such as altering critical values of statistical tests or procedures that might be more appropriate for autocorrelated data.

10. Are [illegible] appropriate for new [illegible]

11. EPA needs information [illegible] be used to evaluate the frequency control comparison and to determine an acceptable range for them.

V. Regulatory Analysis

A. [illegible]

Small businesses should be favorably affected because it is possible that fewer entities will unnecessarily trigger cleanup or extensive ground-water investigations. Thus, fewer will be required to continue the process of modifying the permit. At this point, EPA has not determined the number of small businesses potentially affected in the regulated community, but will investigate this before proposing a rule.

B. Paperwork Reduction Act

This new approach should reduce the total amount of paperwork an owner or operator must complete by reducing the number who must do further characterization of a facility which is falsely identified as contaminating ground water. This further characterization is much more burdensome than additional samples which may be required for revising facility permits. This advance notice of proposed rulemaking is a condition of continuing clearance of the current information collection request.

List of Subjects

40 CFR PART 264

Hazardous material, Insurance, Packaging and containers, Reporting requirements, Security measures, Surety bonds, Waste treatment and disposal.

40 CFR PART 265

Hazardous material, Insurance, Packaging and containers, Reporting requirements, Security measures, Surety bonds, Waste treatment and disposal.

Dated: August 11, 1986.

Lee M. Thomas,

Administrator.

[FR Doc. 86-18648 Filed 8-19-86; 8:45 am]

BILLING CODE 6560-50-M

- Description of Statistical Procedure for Detection of Ground Water Contamination at Hazardous Waste Land Disposal Facilities

DESCRIPTION OF STATISTICAL PROCEDURES FOR DETECTION OF GROUND-WATER CONTAMINATION AT HAZARDOUS WASTE LAND DISPOSAL FACILITIES

Introduction

This memo describes three statistical procedures for detecting ground-water contamination that are presently under consideration. Dunnett's procedure simultaneously compares each downgradient well with a control (upgradient). Steel's procedure is a nonparametric version of Dunnett's using a rank sum statistic in place of a t-statistic. If data are extremely nonnormally distributed, they may either be transformed to approximate normality and analyzed by Dunnett's, or analyzed in their original form by Steels' procedure. To apply Steel's test, however, may require additional sampling since it may be much less powerful with a small number of samples per well. Both of these procedures may also be used to test for overall contamination across downgradient wells.

Individual well contamination may also be detected by use of control charts. These charts compare current samples with historical data from the same well. The use of all three procedures is currently under consideration for detecting ground-water contamination at hazaradous waste land disposal facilities.

Dunnett's Procedure

Dunnett's procedure is a parametric test that simultaneously compares the sample mean for each of p treatment groups to the sample mean for a control group. Each treatment group mean that differs from the control group mean by a given threshold, or "allowance," is declared to be significantly different from the control group mean. The experimentwise level of significance is maintained at a prescribed value, α.

In the present context, the control group is the upgradient well and the treatment groups are p downgradient wells. The Null Hypothesis under test is that the population means of the downgradient wells ($\mu_i, i=1 \le i \le p$) are all equal to the population mean for the upgradient well (μ_0):

$$H_0: \mu_i = \mu_0 \qquad \text{for every } i,\ 1 \le i \le p\ .$$

The Alternative Hypothesis is that the population mean for at least one of the downgradient wells is greater than that of the upgradient well;

$H_A: \mu_i > \mu_o$, for at least one i, $1 \le i \le p$.

The assumptions required for Dunnett's procedure to be valid are that the (p+1) samples are independent, and that each is a random sample from a normal distribution with a common variance.

The test statistic for each downgradient well is the familiar t-statistic

$$T_i = \frac{\bar{X}_i - \bar{X}_o}{S_p\sqrt{2/n}}, \qquad 1 \le i \le p,$$

where $\bar{X}_i$ is the sample mean for the i-th downgradient well, $\bar{X}_o$ is the sample mean for the single upgradient well, S_p is the pooled estimate of the standard deviation from all p+1 wells, and n is the sample size which is the same for all (p+1) wells.

Critical points for α=.01 and α=.05 were tabled by Dunnett (1955) and are included in the appendix. The degrees of freedom (d.f.) required to enter the table is equal to the sum of the sample sizes for all wells minus (p+1). Here, d.f. = (p+1)(n-1), since the sample size is the same for each well. If d (which depends on d.f., p and α) is the appropriate critical point, we reject H_o if , for any downgradient well, $T_i \ge$ d or equivalently if

$$(\bar{X}_i - \bar{X}_o) \ge S_p\sqrt{2/n}\ d$$

for at least one i, $1 \le i \le p$. The right-hand side of the above equation, $(S_p\sqrt{2/n}\ d)$, is referred to as the allowance. If the difference between the sample mean for the i-th downgradient well and the upgradient well exceeds the "allowance," we reject H_o and conclude that $\mu_i > \mu_o$.

Example

The following table gives raw data (4 independent readings from each of 5 wells) and summary statistics for TOX in parts per billion.

	Well Number				
	0	1	2	3	4
	64.8	68.4	66.3	64.7	64.2
	64.2	69.7	66.2	65.3	64.5
	65.0	68.6	65.7	65.0	64.3
	64.7	67.7	66.8	65.1	64.3
Σx	258.7	274.4	265.0	260.1	257.3
$\bar{x}_i$	64.675	68.600	66.250	65.025	64.325
$\bar{x}_i - \bar{x}_o$	NA	3.925	1.575	.350	-.350
Σx^2	16,731.77	18,825.90	17,556.86	16,913.19	16,550.87
S_i^2	.11583	.68667	.20333	.06250	.01583
T_i	NA	11.92	4.78	1.06	-1.06

For each well, the sample variance S_i^2 is equal to $(\Sigma x^2 - n\bar{x}_i^2)/(n-1)$. Since the sample sizes are all equal, the pooled estimate of the variance is simply the average of the individual estimates of the variance: $S_p^2 = (.11583 + .68667 + .20333 + .06250 + .01583)/5 =$ .21683 , which yields $S_p = .46565$ and $S_p\sqrt{2/n} = .32927$.

In this example p=4, n=4, and d.f. = (p+1)(n-1) = 15. From Table 1a* of the appendix the .05 level critical point is 2.36. We see that $T_i \geq 2.36$ for well numbers 1 and 2. Thus, we conclude that the levels of TOX observed in wells 1 and 2 are significantly higher than the level observed in the upgradient well. Equivalently, we can calculate the "tolerance" $S_p\sqrt{2/n}\ d = (.32927)(2.36) = .777$ and compare each difference $(\bar{x} - \bar{x}_o)$ to this tolerance.

Occasionally, sample sizes will not be equal across all wells. This may occur accidentally or by design. For a given sample size, the optimal allocation of measurements calls for somewhat heavier sampling of the upgradient well. For example, 6 measurements for the upgradient well and 4 measurements from each of 4 downgradient wells is optimal among designs with a total of 22 measurements.

When analyzing data with unequal sample sizes, the procedure is similar. The test statistic is formulated as

$$T_i = \frac{\bar{x}_i - \bar{x}_o}{S_p \sqrt{\frac{1}{n_o} + \frac{1}{n_i}}}, \qquad i=1 \le i \le p,$$

where n_o and n_i are the sample sizes for the upgradient and i-th downgradient wells, respectively. The degrees of freedom is given by d.f.$=\sum(n_i-1)=(\sum n_i-p-1)$ and S_p^2 can be calculated as $S_p^2 = \sum(n_i-1)s_i^2/\text{d.f.}$ The critical point obtained from Table 1a* will provide an approximate .05 α-level test. (Dunnett [1964] gives a method for adjusting critical points for unequal sample sizes when making two-sided comparisons.)

The test procedure can be easily modified to allow for inherent well differences by testing the Null Hypothesis

$$H_o: \mu_i = \mu_o + \Delta_i, \qquad \text{for every } i,\ 1 \le i \le p,$$

versus

$$H_A: \mu_i > \mu_o + \Delta_i, \qquad \text{for at least one } i,\ 1 \le i \le p,$$

increasing the i-th "allowance" by Δ_i or equivalently formulating the test statistic as

$$T_i = \frac{\bar{x}_i - \bar{x}_o - \Delta_i}{S_p \sqrt{2/n}}$$

Two-sided tests may also be required for some constituents, such as pH. In this case, we reject the Null Hypothesis for unusually small values of T_i as well as large values. Critical points for two-sided tests can also be found in Dunnett (1955).

It may be desirable to compare the average downgradient well to the upgradient well. This can be done by formulating t-statistic as

$$T_i = \frac{\frac{\bar{x}_1 + \bar{x}_2 + \bar{x}_3 + \bar{x}_4}{4} - \bar{x}_0}{S_p \sqrt{1.25/n}} .$$

In fact, any contrast of the μ_i, say $\sum w_i\mu_i$, can be tested using the statistic $\sum w_i\bar{x}_i/(S_p\sqrt{\sum w_i^2/n_i})$.

Steel's Procedure

Steel's procedure is a nonparametric rank test that simultaneously compares each of p treatment groups to the single control group for shifts in location. Each treatment group for which the rank sum exceeds the critical value is declared to have a greater mean (or median or other location value) than does the control group. The experimentwise level of significance is maintained at a prescribed value, α.

In the present context, the control group is the upgradient well and the treatment groups are p downgradient wells. Suppose f(x) is the density function of the upgradient well. A distribution that differs from f(x) by a shift in location will have density $f(x-\theta)$ for some $\theta \neq 0$. Steel's procedure tests the Null Hypothesis that the downgradient wells all have the same distribution as the upgradient well;

$$H_0: \theta = 0 , \quad \text{for every } i,\ 1 \le i \le p .$$

The Alternative Hypothesis is that at least one of the downgradient wells has a location parameter greater than 0;

$$H_A: \theta > 0 , \quad \text{for at least one } i,\ 1 \le i \le p .$$

The assumptions required for Steel's procedure to be valid are that the (p+1) samples are independent and that each is a random sample from the same continuous distribution, except for possible differences in location.

The test statistic for each downgradient well is the familiar Wilcoxon Rank Sum statistic. Computation of this statistic for the i-th downgradient well requires three steps:

(1) Pool the data for the i-th treatment group with the data for the control group;

(2) Rank the pooled data from smallest to largest; and

(3) Compute the sum of the ranks, R_i, assigned to the treatment group.

Critical points for α=.01 and α=.05 are given in Miller (1966) and Steel (1959). (The table in Steel (1959) gives critical points for $R_i' = (2n+1)n-R_i$.) Use of these tables requires that the sample sizes for each well be equal to n. The tables from Miller (1966) are reproduced in the appendix. If d (which depends on n, p and α) is the appropriate critical point, we reject H_0 if $R_i \geq d$, for at least one i, $1 \leq i \leq p$, where R_i is the Wilcoxon Rank Sum statistic.

If ties are encountered, first attempt to break ties by referring to the raw data to see if the values were recorded to more decimal places. Assign midranks to any remaining ties. Alternatively, we can assign ranks conservatively (anti-conservatively) to obtain a conservative (anti-conservative) test. This technique will be illustrated in the example below.

Example

The following table gives raw data (4 independent readings from 5 wells) for TOX in parts per billion. The numbers in parenthesis are the ranks. (For upgradient well 0, the first number in parenthesis is the rank for the comparison with well 1, the second number is the rank for the comparison with well 2, etc.)

	Well Number			
0	1	2	3	4
64.8(3,3,4,7)	68.4(6)	66.3(7)	64.7(2.5)	64.2(1.5)
64.2(1,1,1,1.5)	69.7(8)	66.2(6)	65.3(8)	64.5(5)
65.0(4,4,5.5,8)	68.6(7)	65.7(5)	65.0(5.5)	64.3(3)
64.7(2,2,2.5,6)	67.7(5)	66.8(8)	65.1(7)	64.3(4)
Sum of Ranks R_i:	26	26	23	13.5

Referring to Steel (1959) we can compute the .05 level critical point for n=4 and p=4 to be 26. We see that $R_i \geq 26$ for i=1 and 2. Thus we conclude that the levels of TOX in downgradient wells 1 and 2 are greater than the level in the upgradient well.

Note that ties resulted when analyzing the results from wells 3 and 4. Even with anticonservative rank assignments (i.e., 3, 6, 7 and 8 for well 3 and 2, 3, 4, and 5 for well 4) the critical value of 26 would not have been reached. Thus, there is insufficient evidence to conclude that TOX levels in either well 3 or 4 are greater than the TOX level in the upgradient well.

In order to achieve the critical point of 26 in this particular example, all the values for the downgradient well being compared must exceed all the values for the upgradient well, i.e., there must be no overlap. This example points out the relative insensitivity of the Wilcoxon statistic to mean differences in certain circumstances. With larger sample sizes, lack of overlap is not required for the null hypothesis to be rejected. Still, if the underlying distribution is normal, Steel's procedure is not as powerful as Dunnett's. On the other hand, with certain non-normal data, Steel's procedure can be more powerful than Dunnett's.

Variations on Steel's Procedure

Suppose the sample sizes are the same for the downgradient wells, but we have a different sample size for the upgradient well. In this case the computational procedure is the same, but special critical points must be used. (See Miller (1966, p151)). A larger sample size for the upgradient well can provide a more efficient test.

The procedure can be easily modified to allow for inherent well differences by testing the Null Hypothesis

$$H_o: \theta_i = \Delta_i , \qquad \text{for every } i,\ 1 \le i \le p,$$

versus

$$H_A: \theta_i > \Delta_i , \qquad \text{for at least one } i,\ 1 \le i \le p,$$

This is accomplished by first subtracting Δ_i from each sample value for the i-th well, and then proceeding as before.

Two-sided tests may also be required for some constituents, such as pH. In this case, we reject the Null Hypothesis for large values of R_i, or large values of its complement $R_i' = (2n+1)n - R_i$. Critical points for two-sided tests can be found in Miller (1966) and Steel (1959).

It may be desirable to compare the average downgradient well to the upgradient well. This can be done by first pooling the data for all downgradient wells. We now make only one comparison using the standard Wilcoxon two-sample test. If all downgradient wells are contaminated to about the same degree, this test is more powerful than Steel's procedure applied to multiple downgradient wells.

Control Charts

Control charts can be used to monitor contaminant levels over time to detect differences from historical readings. Average readings for each month are plotted along with a measure of their variability; if particular readings differ from historical averages by a significant level then a change from past levels is indicated. Slight changes in average constitutent levels along with steadily increasing contamination can also be detected.

The Null Hypothesis under test is that the average level (μ_{it}) of constituent at a particular well has remainded steady since baseline sampling.

$$H_o: \mu_{it} = \mu_{io} \quad \text{for each well } i, \text{ for all time } t \ge 1.$$

The Alternative Hypothesis is that the constituent level has increased.

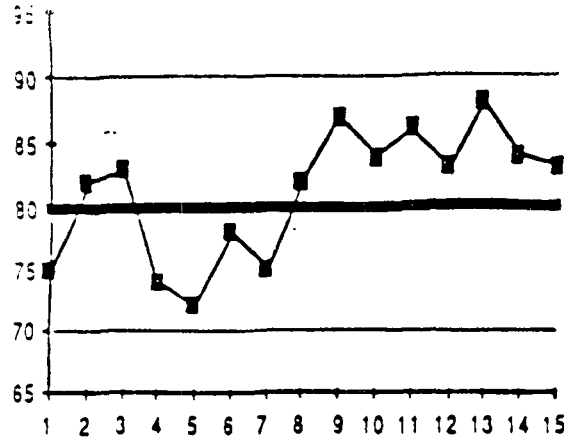
H_A: $\mu_{it} > \mu_{io}$ for some well i, at some time $t \geq 1$.

There are two assumptions required for control charts. The samples which are averaged to plot as a value on the chart must be sufficient in number for the averages to be approximately normally distributed, and each set of samples must be independent of each other.

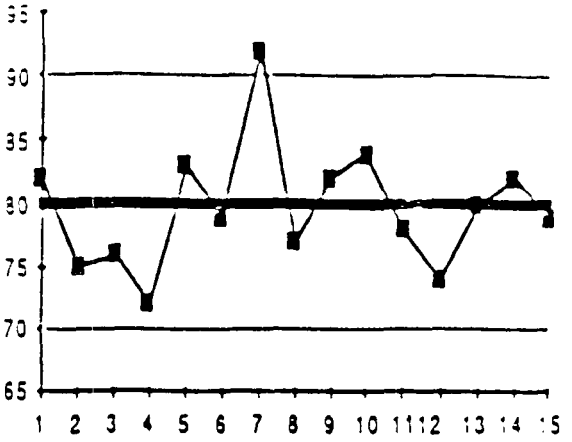
The test procedure is to set bounds (control limits) based upon the average of the monthly plotted averages and the average monthly variability beyond which it would be extremely unlikely for an average value to fall if the null hypothesis is true. Increases in the constituent level will cause values to exceed these control limits and the null hypothesis to be rejected. In addition to being rejected bacause of a radical departure from past levels, the null hypothesis will also be rejected if eight successive average values are above the historical average or if six successive averages are monotonically increasing. These latter two checks will detect a small but consistent increase in contamination and continually increasing levels of contamination, respectively. While a constant level of variability is not being tested in the hypothesis, it is still necessary to chart it monthly. If the variability exceeds its control limits or exhibits runs or trends, it will indicate a need to revise the limits for average constituent level. This is the only reason for recomputing these limits.

Example

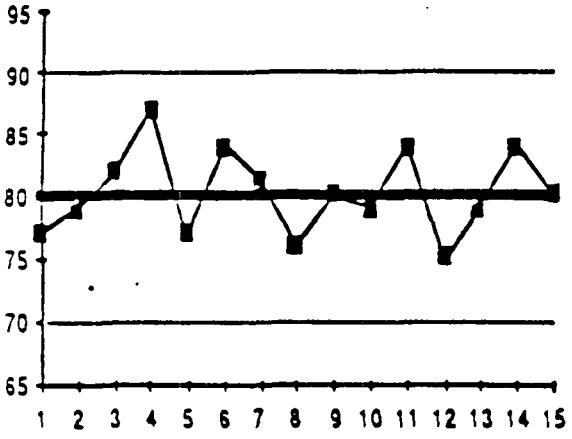
The following four graphs of TOX in parts per billion at a particular well demonstrate these rules. In all cases, the historical average level has been 80 ppb. In graph a, a persistant change to levels of approximately 85 ppb has been indicated by eight successive readings above the historical average. In graph b, a one-time level of 92 ppb in quarter 7 exceeds the upper control limit of 90 indicating contamination. Graph c shows a stable level of constituent in the ground water. Graph d shows a trend of 7 (6 would have been sufficient) successive quarterly readings that increase. This pattern of ground-water contamination is again reason to reject the null hypothesis. Only graph c would not indicate increased contamination.



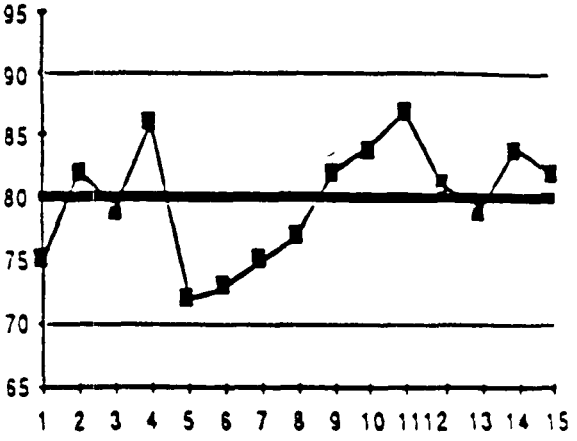
(a)



(b)



(c)



(d)

Construction of Control Limits

To construct the control limits, it is first necessary to compute the average, $\bar{x}$, and range, R, of each set of sample readings. The historical averages are then found by averaging these numbers over the baseline period. These historical averages are called $\bar{\bar{x}}$ and $\bar{R}$. If UCL and LCL stand for upper and lower control limits, respectively, then the formulas for constructing the control limits for the ranges are:

$$UCL_R = D_4\bar{R} \quad \text{and} \quad LCL_R = D_3\bar{R}$$

and for the averages

$UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$ and $LCL_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}$

The following table gives the values of D_4, D_3, and A_2 for different numbers of samples (n) used to compute each $\bar{x}$ and R. More extensive tables are available in Grant and Leavenworth (1980).

n	2	3	4	5	6	7	8
D_4	3.27	2.57	2.28	2.11	2.00	1.92	1.86
D_3	0	0	0	0	0	0.08	0.14
A_2	1.88	1.02	0.73	0.58	0.48	0.42	0.37

Variations on Control Charts

At least four variations on control charts may be appropriate: adjustments for seasonality, testing for improvement, usng individual readings, and simultaneously testing multiple constituents.

Many hazardous waste facilities have significant seasonal variability in constituent levels. This background seasonality may be adjusted for by computing separate monthly (or quarterly) averages during the two-year baseline period. Future values would then be adjusted for these monthly (quarterly) seasonal differences before being plotted on the control chart.

The same control chart that is constructed to detect contamination can also detect improvements over past levels. This is indicated by averages below the lower control limit, runs below the historical average, or downward trends. This use of control charts may be helpful for corrective action and detection monitoring. If a site has improved, they could be judged against this revised standard rather than the initial levels.

If in each time period only one reading is collected, it is impossible to plot average values. This requires two modifications to the above procedure. Without averaging, it becomes necessary for the individual readings to be normally distributed. If this is not the case, the data must be transformed to an approximately normal distribution before plotting or limits computed based on the alternative distribution. Ranges within time periods can also no longer be computed. These are replaced by ranges between successive pairs (or triples, etc.) of time periods. The value of n for determining the table constants is now 2 (or 3, etc.). The constant A_2 is also replaced by E_2 given in the following table:

n	2	3	4	5	6	7	8
E_2	2.66	1.77	1.46	1.29	1.18	1.11	1.05

Due to the large number of constituent/well combinations it may be advantageous to collapse multiple constitutents or wells together on one chart. The resulting control chart uses a χ^2 distribution instead of a normal distribution and has only an upper control limit. The disadvantage is that if the chart indicates contamination, it is not necessarily obvious which particular constituent or well is contaminated. See Alt (1985) for further details.

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Table 1a. Dunnett's Procedure: Table of t for one-sided comparisons between p treatment means and a control for a joint confidence coefficient of P = 95%

	p, Number Of Treatment Means (Excluding The Control)								
d.f.	1	2	3	4	5	6	7	8	9
5	2.02	2.44	2.68	2.85	2.98	3.08	3.16	3.24	3.30
6	1.94	2.34	2.56	2.71	2.83	2.92	3.00	3.07	3.12
7	1.89	2.27	2.48	2.62	2.73	2.82	2.89	2.95	3.01
8	1.86	2.22	2.42	2.55	2.66	2.74	2.81	2.87	2.92
9	1.83	2.18	2.37	2.50	2.60	2.68	2.75	2.81	2.86
10	1.81	2.15	2.34	2.47	2.56	2.64	2.70	2.76	2.81
11	1.80	2.13	2.31	2.44	2.53	2.60	2.67	2.72	2.77
12	1.78	2.11	2.29	2.41	2.50	2.58	2.64	2.69	2.74
13	1.77	2.09	2.27	2.39	2.48	2.55	2.61	2.66	2.71
14	1.76	2.08	2.25	2.37	2.46	2.53	2.59	2.64	2.69
15	1.75	2.07	2.24	2.36	2.44	2.51	2.57	2.62	2.67
16	1.75	2.06	2.23	2.34	2.43	2.50	2.56	2.61	2.65
17	1.74	2.05	2.22	2.33	2.42	2.49	2.54	2.59	2.64
18	1.73	2.04	2.21	2.32	2.41	2.48	2.53	2.58	2.62
19	1.73	2.03	2.20	2.31	2.40	2.47	2.52	2.57	2.61
20	1.72	2.03	2.19	2.30	2.39	2.46	2.51	2.56	2.60
24	1.71	2.01	2.17	2.28	2.36	2.43	2.48	2.53	2.57
30	1.70	1.99	2.15	2.25	2.33	2.40	2.45	2.50	2.54
40	1.68	1.97	2.13	2.23	2.31	2.37	2.42	2.47	2.51
60	1.67	1.95	2.10	2.21	2.28	2.35	2.39	2.44	2.48
120	1.66	1.93	2.08	2.18	2.26	2.32	2.37	2.41	2.45
inf.	1.64	1.92	2.06	2.16	2.23	2.29	2.34	2.38	2.42

* Table 1a gives a solution d' of to equation (4) in the text for $P = .95$ for the case $\rho_{ij} = 1/2$.

Table 1b. Dunnett's Procedure: Table of t for one-sided comparisons between ρ treatment means and a control for a joint confidence coefficient of P = 99%

	p, Number Of Treatment Means (Excluding The Control)								
d.f.	1	2	3	4	5	6	7	8	9
5	3.37	3.90	4.21	4.43	4.60	4.73	4.85	4.94	5.03
6	3.14	3.61	3.88	4.07	4.21	4.33	4.43	4.51	4.59
7	3.00	3.42	3.66	3.83	3.96	4.07	4.15	4.23	4.30
8	2.90	3.29	3.51	3.67	3.79	3.88	3.96	4.03	4.09
9	2.82	3.19	3.40	3.55	3.66	3.75	3.82	3.89	3.94
10	2.76	3.11	3.31	3.45	3.56	3.64	3.71	3.78	3.83
11	2.72	3.06	3.25	3.38	3.48	3.56	3.63	3.69	3.74
12	2.68	3.01	3.19	3.32	3.42	3.50	3.56	3.62	3.67
13	2.65	2.97	3.15	3.27	3.37	3.44	3.51	3.56	3.61
14	2.62	2.94	3.11	3.23	3.32	3.40	3.46	3.51	3.56
15	2.60	2.91	3.08	3.20	3.29	3.36	3.42	3.47	3.52
16	2.58	2.88	3.05	3.17	3.26	3.33	3.39	3.44	3.48
17	2.57	2.86	3.03	3.14	3.23	3.30	3.36	3.41	3.45
18	2.55	2.84	3.01	3.12	3.21	3.27	3.33	3.38	3.42
19	2.54	2.83	2.99	3.10	3.18	3.25	3.31	3.36	3.40
20	2.53	2.81	2.97	3.08	3.17	3.23	3.29	3.34	3.38
24	2.49	2.77	2.92	3.03	3.11	3.17	3.22	3.27	3.31
30	2.46	2.72	2.87	2.97	3.05	3.11	3.16	3.21	3.24
40	2.42	2.68	2.82	2.92	2.99	3.05	3.10	3.14	3.18
60	2.39	2.64	2.78	2.87	2.94	3.00	3.04	3.08	3.12
120	2.36	2.60	2.73	2.82	2.89	2.94	2.99	3.03	3.06
inf.	2.33	2.56	2.68	2.77	2.84	2.89	2.93	2.97	3.00

* Table 1b gives a solution $df = t$ to equation (4) in the text for $P = .99$ for the case $\rho_{ij} = 1/2$.

Table 2. Percentage points for Steel's procedure
(k downgragient wells, n samples from each well)

(One-tailed)

	α = .05									α = .01								
n \ k	2	3	4	5	6	7	8	9	10	2	3	4	5	6	7	8	9	10
5	-	-	-	-	-	-	-	-	-									
6	6	-	-	-	-	-	-	-	-									
7	7	7	7	-	-	-	-	-	-									
8	8	8	8	8	8	8	8	-	-									
9	8	9	9	9	9	9	9	9	9	9	-	-	-	-	-	-	-	-
10	9	9	9	10	10	10	10	10	10	10	10	10	-	-	-	-	-	-
11	10	10	10	10	10	10	11	11	11	11	11	11	11	11	11	11	-	-
12	10	11	11	11	11	11	11	11	11	11	12	12	12	12	12	12	12	12
13	11	11	11	12	12	12	12	12	12	12	12	13	13	13	13	13	13	13
14	12	12	12	12	12	12	13	13	13	13	13	13	13	13	14	14	14	14
15	12	13	13	13	13	13	13	13	13	13	14	14	14	14	14	14	14	14
16	13	13	13	14	14	14	14	14	14	14	14	15	15	15	15	15	15	15
17	13	14	14	14	14	14	15	15	15	15	15	15	15	16	16	16	16	16
18	14	14	15	15	15	15	15	15	15	15	16	16	16	16	16	16	16	17
19	15	15	15	15	16	16	16	16	16	16	16	17	17	17	17	17	17	17
20	15	16	16	16	16	16	16	17	17	17	17	17	17	18	18	18	18	18
25	18	19	19	19	19	19	20	20	20	20	20	20	21	21	21	21	21	21
30	21	22	22	22	22	23	23	23	23	23	23	24	24	24	24	24	24	24
35	24	25	25	25	25	26	26	26	26	26	26	27	27	27	27	27	27	28
40	27	28	28	28	28	29	29	29	29	29	30	30	30	30	30	30	31	31
45	30	31	31	31	31	32	32	32	32	32	33	33	33	33	33	34	34	34
50	33	33	34	34	34	34	35	35	35	35	36	36	36	36	36	37	37	37
100	61	61	62	62	63	63	63	63	64	64	65	65	65	66	66	66	66	66

Table 2. Percentage points for Steel's procedure (continued)
(k downgragient wells, n samples from each well)

(Two-tailed)

	α = .05								α = .01							
n \ k	2	3	4	5	6	7	8	9	2	3	4	5	6	7	8	9
6	-	-	-	-	-	-	-	-								
7	7	-	-	-	-	-	-	-								
8	8	8	8	-	-	-	-	-								
9	9	9	9	9	9	-	-	-	-	-	-	-	-	-	-	-
10	9	10	10	10	10	10	10	10	10	-	-	-	-	-	-	-
11	10	10	11	11	11	11	11	11	11	11	11	-	-	-	-	-
12	11	11	11	11	12	12	12	12	12	12	12	12	12	-	-	-
13	11	12	12	12	12	12	12	12	13	13	13	13	13	13	13	13
14	12	12	13	13	13	13	13	13	13	13	14	14	14	14	14	14
15	13	13	13	13	14	14	14	14	14	14	14	14	15	15	15	15
16	13	14	14	14	14	14	14	14	15	15	15	15	15	15	15	15
17	14	14	15	15	15	15	15	15	15	15	16	16	16	16	16	16
18	15	15	15	15	16	16	16	16	16	16	16	17	17	17	17	17
19	15	16	16	16	16	16	16	16	17	17	17	17	17	17	18	18
20	16	16	17	17	17	17	17	17	17	18	18	18	18	18	18	18

- 50 FR 219:46906 (November 13, 1985)
  "Method Dectection Limits and Practical Quantitation Levels"

qualitative identifications are indeed the compounds of interest. However, since some VOCs are amenable to both photoionization and halogen specific detectors, the second detector may provide the same degree of confirmation as a second column analysis.

A mass spectrometer usually is able to discriminate between the compounds of interest and interfering compounds. Thus, it is the preferred detection system to provide unequivocal identification in such cases.

c. *Laboratory Availability.* There are approximately 90 laboratories which participate regularly in EPA's Water Pollution performance evaluation studies for VOCs. In addition, there are approximately 200 laboratories which participate regularly in EPA's Water Supply performance evaluation studies for trihalomethanes (THMs). The principles of sample collection and analysis for VOCs are similar to those used for the determination of the four regulated THMs except that the THM MCL (0.10 mg/l) is about 2 orders of magnitude higher than the limits being proposed for the VOCs. The selected procedures use equipment and skills available in many drinking water laboratories. Therefore, EPA feels that there are analytical laboratories available with the expertise required to conduct VOC analysis on a routine basis.

Vinyl chloride, however, presents special analytical problems in the analysis, especially at concentrations near 1 µg/L. Reliable preparation and analysis of samples for vinyl chloride is expected only from the most experienced laboratories. Thus, few laboratories are available to measure vinyl chloride at concentrations near 1 µg/l routinely. Since the proposed monitoring regime (see Section V) would require fewer analyses for vinyl chloride on the most experienced laboratories would be expected to be used for vinyl chloride analysis.

d. *Rapidity.* Estimated analysis time including sample preparation and quality assurance is about one hour per sample. This is comparable to the analysis time required for THM analysis. The selected methods are sufficiently rapid to permit routine use in the examination of a large number of samples.

e. *Costs.* EPA conducted an assessment of analytical costs associated with the analysis of VOCs in drinking water. This assessment included 28 commercial laboratories chosen from those participating in EPA's performance evaluation sample program and which are performing VOC analyses by methods consistent with the proposed methods. The cost comparison below summarized the findings.

COST COMPARISON OF VOC ANALYSES

	GC/MS	GC
Average cost	$197	$157
Range	50–300	75–500
Number of laboratories	23	13

[1] Includes both halocarbons and aromatics by HSD and PID, respectively.

The average quote for the sum of separate VOC analyses using GC with halogen-specific and photoionization detection for halocarbons and aromatics, respectively, was $187 per sample and ranged from $75 to $500 per sample. The average cost of VOC analysis using GC/MS was $197 per sample, and ranged from $50 to $300 per sample. The range in prices quoted by the laboratories may be due to differences in the number of samples analyzed routinely by these laboratories and the amount of quality assurance associated with the analyses. These costs were quoted for analysis for all VOCs listed in the methods or about 60 VOCs. When asked for quotes for just 10 VOCs, the laboratories generally stated it would be the same quote: 2 of the 13 GC laboratories quoted $25 per sample less and 3 of the 23 GC/MS laboratories quoted $50 per sample less. These quotes took into account that analysis of all nine VOCs may require two analyses depending upon the equipment in a particular laboratory. In addition, a confirmatory secondary column analysis might be needed for some VOCs in cases where GC/MS is not used.

The analysis of VOCs using the photoionization and electrolytic conductivity detectors in series has been reported by some laboratories. Methods 502.1 and 503.1 include use of detectors in series as an alternate. Simultaneous analysis of volatile halocarbons and aromatic hydrocarbons most likely will result in lower analytical costs (total cost estimated at about $150 per sample). EPA expects that many analytical laboratories will opt to use detectors in series or GC/MS, and that the analytical costs will thereby be reduced.

2. Method Detection Limits and Practical Quantitation Levels

In general, EPA defines the method detection limit (MDL) as the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the true value is greater than zero. The specification of such a concentration is limited by the fact that MDLs are a variable affected by the performance of a given measurement system. MDLs are not necessarily reproducible over time in a given laboratory, even when the same analytical procedures, instrumentation and sample matrix are used.

The lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions is the Practical Quantitation Level (PQL). The PQL thus represents the lowest level achievable by good laboratories within specified limits during routine laboratory operating conditions. The PQL is determined through inter-laboratory studies, such as the PE studies. Differences between MDLs and PQLs are expected since the MDL represents the lowest achievable level under ideal laboratory conditions whereas the PQL represents the lowest achievable level under practical and routine laboratory conditions.

If data are unavailable from inter-laboratory studies, PQLs are estimated based upon the MDL and an estimate of a higher level which would represent a practical and routinely achievable level with relatively good certainty that the reported value is reliable. Traditionally, this level has been estimated at 5 to 10 times the MDL. EPA believes that setting the PQLs in a range between 5 and 10 times the MDL achieved by the best laboratories is a fair expectation for most State and commercial laboratories. Public comment are specifically requested on the expectation that 5 to 10 times the MDL is a good general rule as to what levels can be expected to be measured by commercial laboratories with reliability.

A recent survey of seven U.S. EPA laboratories and contract laboratories serving the EPA reported MDLs averaging from 0.2 to 0.5 µg/l for the nine VOCs in this proposed regulation. The approximate MDLs of 0.2 to 0.5 µg/l are the result of measurement made by a few of the most experienced laboratories under non-routine and very controlled conditions. These levels are not expected to be representative of the capabilities of a cross-section of good laboratories performing compliance VOC measurements on a routine basis.

The PQLs for the VOCs have been determined based primarily upon the results of performance data from EPA and non-EPA sources, multi-laboratory method validation studies and performance evaluation studies. Table 2 provides a summary of recent WP performance evaluation studies by EPA and State laboratories (WP studies #3–11). This table summarizes the result if the limits of precision and accuracy were set at ±20% and ±40% of the reference "true" value for VOC

ATTACHMENT B

DATA BASE FOR THE DEMONSTRATION

ATTACHMENT B

DATA BASE FOR THE DEMONSTRATION

The size and quality of the available site-specific data base for the Bayou Sorrel site is not sufficient for the purposes of this demonstration. The existing data consist of a maximum of two to four sampling dates per well taken by different investigators and analyzed by different labs over a period of about five years. Therefore, real well data from a similar site in coastal Louisiana (herein after referred to as the surrogate site) were compiled and used to construct a hypothetical data base for the Bayou Sorrel statistical performance demonstration. This data base and the results of statistical analysis for the data base are presented for illustrative purposes only. No conclusions drawn from the analyses presented herein are applicable to the Bayou Sorrel site other than the applicability of the statistical procedures demonstrated herein.

Data from the surrogate site span a time period from 1981 to 1986 and include a total of 14 dates of sample. The data include both replicated and unreplicated samples. A total of 17 wells were sampled and analyzed during this time period for the parameters of interest, namely the water quality parameters (SC, TOC, pH, SO_4, and Cl) and the indicator parameters (As, Cd, Cr, Pb, and phenol) which will be monitored at the Bayou Sorrel site. No ethylbenzene data were available from the surrogate site. The raw data base from the surrogate site is summarized in Table B-1.

In the interest of time, the data were reviewed and three parameters were selected for use in the statistical performance demonstration, based on the following criteria:

1. Each parameter selected had to have results for as many dates of sample as possible.

2. The parameter had to have been analyzed consistently in at least 11 wells other than the two upgradient wells in order to model the well field that will exist at the North Area of the Bayou Sorrel site.

3. Among the three parameters chosen, at least one had to display a normal distribution either for the entire well field or, at the least, for the background data set.

Parameters chosen for further analysis in the demo were SC, pH and TOC. TOC is strongly left-skewed (Figure B-1). In fact, the TOC data almost describe an exponential decay function for both the well field as a whole. The replicated TOC background

TABLE B-1

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
10/24/81	L3	1	0	6.87	5900	63	3.6	3800	1	5	50	10	71
05/07/82		1	195	6.37	9100	112		4400			50	50	11
07/27/82		1	276	6.49	10600	87	15.3	4400	81	5	50	90	20
11/04/82		1	376	6.48	9800	141	12	4200	14	5	100	200	10
01/13/83		1	446	6.3	11600	65.6	52.4	3859	31	0.03	1	239	50
10/24/81	L5	2	0	7.84	4900	97	2.5	1800	1	5	50	10	57
05/07/82		2	195	6.6	6900	107		2850			50	50	8
07/27/82		2	276	6.93	8100	1	50	2900	380	5	50	50	22
11/04/82		2	376	6.77	6500	220	23	2600	87	33	100	400	20
01/13/83		2	446	6.5	8400	72.5	103.4	2699	8	0.74	1	190	50
04/14/83		2	537	6.6	9720	33.8	74.7	3024	84	4.3	4	34	50
09/22/83		2	698	6.74	9000	39.4	17.3	3318	21	9.7	19	17	50
		2	698	6.75	8900	40.4							
		2	698	6.7	9000	36							
		2	698	6.72	9000	36.1							
12/08/83		2	776	7.78	9800	83	104.3	3719	22	1.8	2	11	50
		2	776	7.8	9800	83.2							
		2	776	7.75	9800	82.6							
		2	776	7.78	9900	79.5							
05/30/84		2	949	6.5	11000	82.7							
		2	949	6.63	11000	82.5							
		2	949	6.5	11000	82.4							
		2	949	6.6	10950	83.2							
11/29/84		2	1132	6.88	11500	62.5	169.3	4050					50
		2	1132	6.88	11000	60.9							
		2	1132	6.88	11000	59.7							
		2	1132	6.88	11000	60.2							
10/24/81	L9	3	0	7.62	1350	75	18	150	10	5	50	10	34
05/07/82		3	195	6.31	1130	58		95			50	50	13
07/27/82		3	276	6.84	1340	87	79	160	23	5	50	60	15
11/04/82		3	376										
01/13/83		3	446	6.65	1300	25.3	269.4	72	701	2.2	2	47	50

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
10/24/81	L10	4	0	7.82	14200	42	1	8300	26	6	50	10	23
05/07/82		4	195	6.72	10900	59		5500			50	50	13
07/27/82		4	276	6.89	7000	13	35	2650	54	5	50	50	14
11/04/82		4	376	6.88	12300	73	14	6400	31	19	50	400	52
01/13/83		4	446	6.5	12500	458	177.3	4259	30	0.03	1	145	50
04/14/83		4	537	6.75	12420	40.9	87.7	4024	16	4	1	118	50
09/22/83		4	698	6.7	12600	38.3	28.3	4788	4	10.2	1	24	50
		4	698	6.65	12600	38.76							
		4	698	6.7	12800	39.34							
		4	698	6.7	12800	37.71							
12/08/83		4	776	6.93	15000	106.1	71.8	5978	5	5.3	1	31	80
		4	776	6.9	15300	101.3							
		4	776	6.97	15000	94.9							
		4	776	6.93	15200	94.8							
05/30/84		4	949	6.57	15400	85.3							
		4	949	6.6	15400	83.7							
		4	949	6.61	14850	82.1							
		4	949	6.62	15400	81.8							
11/29/84		4	1132	6.92	15000	59.9	360.5	6250					50
		4	1132	6.92	14000	60.2							
		4	1132	6.92	15000	60.1							
		4	1132	6.92	14000	59.1							
10/24/81	L11	5	0	6.89	2500	270	2	300	1	5	50	10	78
05/07/82		5	195	6.33	1640	179		160			50	50	16
07/27/82		5	276	6.31	1640	141	28	190	98	5	50	50	15
11/04/82		5	376	6.21	2200	149	11	250	180	6	50	200	48
01/13/83		5	446	6.35	1700	84.9	62.9	122	50	0.37	1	46	50
04/14/83		5	537	6.54	1304	51.4	55.7	684	48	1.6	1	3.6	50
09/22/83		5	698	6.5	1400	57.5	35.4	140	4.3	9.2	1	18	50
		5	698	6.5	1390	57.81							
		5	698	6.5	1400	57.6							
		5	698	6.5	1420	57.51							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
12/08/83		5	776	7.14	1350	40.89	63	140	5	0.46	1	3.7	80
		5	776	7.16	1300	40.65							
		5	776	7.21	1300	40.22							
		5	776	7.13	1300	40.16							
05/30/84		5	949	6.49	1430	136							
		5	949	6.48	1480	137							
		5	949	6.47	1430	135							
		5	949	6.47	1480	135							
11/29/84		5	1132	6.79	1400	82	115.8	140					50
		5	1132	6.68	1400	83.4							
		5	1132	6.67	1400	82.8							
		5	1132	6.67	1400	80.8							
10/24/81	L12	6	0	8.28	5700	98	162	2050	1	5	50	10	18
05/07/82		6	195	6.87	5500	102		2050			50	50	25
07/27/82		6	276	7.03	7400	1	66	2600	11	5	50	50	10
11/04/82		6	376	7.13	5000	79	67	2200	11	20	50	200	78
01/13/83		6	446	6.6	7200	40.2	88.6	2369	28	1.7	1	160	50
04/14/83		6	537	6.76	7992	25.25	36.4	2374	32	2.7	2	90	50
09/22/83		6	698	6.68	8800	42.4	22.9	2775	1	9.9	1	26	50
		6	698	6.64	9000	41.41							
		6	698	6.65	8900	42.66							
		6	698	6.62	8800	42.19							
12/08/83		6	776	6.89	9000	36.77	39.1	2299	11	3.2	1	13	80
		6	776	6.83	9000	36.3							
		6	776	6.84	9000	34.27							
		6	776	6.9	9200	34.49							
05/30/84		6	949	6.55	8150	128							
		6	949	6.55	8800	127							
		6	949	6.5	8800	127							
		6	949	6.5	8580	127							
11/29/84		6	1132	6.89	7700	56.4	113.7	2850					50
		6	1132	6.9	7800	56.3							
		6	1132	6.9	7700	57.1							
		6	1132	6.9	7700	57.2							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
10/24/81	L13	7	0	7.56	8800	80	10	3750	1	5	50	10	44
05/07/82		7	195	6.48	8300	135		4050			50	50	24
07/27/82		7	276	6.78	8900	67	16.3	2600	143	9	60	380	25
11/04/82		7	376	6.85	8300	390	14	3400	180	17	110	400	50
		7	376	6.8	8200	360							
		7	376	6.83	8200	460							
		7	376	6.87	8000	410							
01/13/83		7	446	6.35	9600	53.1	66.9	3278	10	3	1	120	100
		7	446	6.5	9700	54.2							
		7	446	6.55	9500	53.6							
		7	446	6.6	9450	51.2							
04/14/83		7	537	6.99	10040	19.52	41.5	2499	59	3.7	9	66	50
		7	537	6.98	9930	18.96							
		7	537	6.98	9990	18.78							
		7	537	6.97	9990	18.88							
09/22/83		7	698	6.36	10000	61.31	27.9	3425	4	9.3	1	23	50
		7	698	6.4	10000	59.89							
		7	698	6.36	10000	61.7							
		7	698	6.34	9800	61.7							
12/08/83		7	776	6.6	10300	94.82	63.9	2879	21	3.7	1	12	150
		7	776	6.62	10000	87.13							
		7	776	6.6	10000	87.7							
		7	776	6.63	10000	87.35							
05/30/84		7	949	6.4	9100	18.8							
		7	949	6.4	9100	19.1							
		7	949	6.4	9100	18.7							
		7	949	6.45	9130	18.6							
11/29/84		7	1132	6.77	8400	89	143.8	3750					50
		7	1132	6.8	8500	84.9							
		7	1132	6.8	8500	84.9							
		7	1132	6.81	8500	84.7							
11/85		7	1497	6.63	1400	29							
02/86		7	1589	6.45	5600	53							
05/86		7	1681	6.55	11000	34							
08/86		7	1773	6.51	10000	28							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
11/04/82	L14	8	376	7.76	1340	410	68	45	140	14	100	300	8
01/13/83		8	446	7	2400	31.2	103.4	480	53	0.82	2	0.8	100
04/14/83		8	537	6.65	9830	18.9	26	1004	62	6.2	14	70	50
09/22/83		8	698	6.7	2900	58.13	15.6	630	6	8.5	1.2	25	50
		8	698	6.72	3000	54.2							
		8	698	6.8	3000	51.37							
		8	698	6.9	3000	50.93							
12/08/83		8	776	6.65	2700	111.3	91.9	530	20	0.54	2	0.8	50
		8	776	6.7	2700	111.9							
		8	776	6.69	2700	112							
		8	776	6.7	2650	112.6							
05/30/84		8	949	6.69	3300	10.2							
		8	949	6.7	3300	10.2							
		8	949	6.7	3300	10.2							
		8	949	6.7	3080	10.3							
11/29/84		8	1132	7.21	2800	41.4	42.6	600					50
		8	1132	7.21	2700	40.7							
		8	1132	7.21	2700	40.6							
		8	1132	7.21	2700	41							
11/85		8	1497	6.83	994	11							
02/86		8	1589	6.71	2940	21							
05/86		8	1681	6.77	3410	25							
08/86		8	1773	6.65	2950	11							
10/24/81	L15	9	0	8.48	1310	73	40	400	19	5	50	10	59
05/07/82		9	195	7.34	3600	121		780			50	50	14
07/27/82		9	276	7.54	3800	4	28	760	29	5	50	50	26
11/04/82		9	376	6.7	3200	160	16	750	48	9	50	50	6
01/13/83		9	446	6.6	3600	81.01	59.4	720	27	1.3	1	134	300
04/14/83		9	537	6.65	3990	47.5	52.4	784	20	2.2	31	52	50
09/22/83		9	698	6.67	4200	95.77	23.2	970	6	10.4	1	39	50
		9	698	6.7	4200	94.52							
		9	698	6.7	4200	91.46							
		9	698	6.7	4300	90.07							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
12/08/83		9	776	6.6	3750	124.9	11.5	970	7	1	2	0.8	80
		9	776	6.63	3800	122							
		9	776	6.6	3800	119.6							
		9	776	6.6	3800	123.2							
05/30/84		9	949	6.7	3850	96.2							
		9	949	6.7	4070	95.8							
		9	949	6.7	4070	95.9							
		9	949	6.72	4070	95.2							
11/29/84		9	1132	6.89	4000	170	25.8	1000					50
		9	1132	6.88	4000	167							
		9	1132	6.88	4000	165							
		9	1132	6.88	4000	166							
10/24/81	L16	10	0	7.2	10700	41	1	6500	1	5	50	10	51
05/07/82		10	195	6.68	10100	113		5100			50	50	13
07/27/82		10	276	6.97	12700	2	19.1	4600	79	5	50	50	11
11/04/82		10	376	7.1	9800	47	13	5100	210	18	50	100	5
		10	376	7	9700	49							
		10	376	6.95	9400	42							
		10	376	6.98	9200	44							
01/13/83		10	446	6.6	13400	51.2	92.7	4858	2	1.3	1	160	50
		10	446	6.65	13450	48							
		10	446	6.5	13200	45.8							
		10	446	6.5	13600	45.2							
04/14/83		10	537	6.76	14040	21.03	63.7	4549	66	6	1	40	50
		10	537	6.73	14040	21.67							
		10	537	6.74	14060	21.43							
		10	537	6.76	14050	21.16							
09/22/83		10	698	6.45	12000	68.29	16.6	4625	20	10	1	36	50
		10	698	6.48	12500	68.06							
		10	698	6.46	12300	67.28							
		10	698	6.4	12000	67.66							
12/08/83		10	776	6.6	11800	98.23	13.2	4689	22	5.1	1	21	110
		10	776	6.58	11000	96.25							
		10	776	6.6	12000	93.52							
		10	776	6.6	11700	87.82							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
05/30/84		10	949	6.55	11000	74							
		10	949	6.55	11000	73.6							
		10	949	6.55	11000	72.8							
		10	949	6.56	11000	73							
11/29/84		10	1132	6.68	12000	106	19.6	5000					50
		10	1132	6.7	11000	107							
		10	1132	6.7	11000	108							
		10	1132	6.7	11000	107							
11/85		10	1497	6.89	1388	25							
02/86		10	1589	6.75	1460	61							
05/86		10	1681	6.62	13800	30							
11/86		10	1773	6.54	13125	28							
10/24/81	L17	11	0	7.58	9000	64	1	4300	1	5	50	10	87
05/07/82		11	195	6.74	8400	111		4300			50	50	32
07/27/82		11	276	6.78	10300	1	23	3900	104	5	50	50	16
11/04/82		11	376	6.54	9000	65	13	4200	200	21	50	100	5
		11	376	6.66	9000	77							
		11	376	6.51	9000	66							
		11	376	6.54	8800	71							
01/13/83		11	446	6.4	10300	76.6	47.9	3809	9	1.4	1	140	50
		11	446	6.4	10350	78.4							
		11	446	6.5	10000	75.6							
		11	446	6.5	10400	65.9							
04/14/83		11	537	6.53	10690	23.53	48.3	3923	47	2.6	6	30	50
		11	537	6.52	10240	21.05							
		11	537	6.51	10360	23.3							
		11	537	6.51	10540	18.82							
09/22/83		11	698	6.39	11000	88.43	9.9	3936	11	9.4	1.4	43	50
		11	698	6.4	11000	90.21							
		11	698	6.4	11000	90.45							
		11	698	6.38	11200	88.71							
12/08/83		11	776	6.6	9800	61.06	21.1	3809	22	5.2	3	17	80
		11	776	6.55	10000	61.41							
		11	776	6.6	10000	62.16							
		11	776	6.55	10000	61.76							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
05/30/84		11	949	6.5	11000	65.5							
		11	949	6.49	11000	70.1							
		11	949	6.5	11000	65.3							
		11	949	6.5	11000	66.1							
11/29/84		11	1132	6.68	9600	96.7	35.2	4300					50
		11	1132	6.59	9800	97.7							
		11	1132	6.59	9600	99.7							
		11	1132	6.59	9800	100.1							
11/85		11	1497	6.74	1588	21							
02/86		11	1589	6.65	9875	75							
05/86		11	1681	6.43	11900	25							
08/86		11	1773	6.51	11875	30							
11/04/82	L18	12	376	9.56	2100	30	133	500	29	5	50	100	52
01/13/83		12	446	6.5	2100	34.7	176.5	340	43	0.6	1	0.8	50
04/14/83		12	537	6.65	3450	57.29	26.5	775	37	1.9	2	53	50
09/22/83		12	698	6.43	4500	133	143.4	1175	5	8.7	1.4	43	50
		12	698	6.44	4500	128.5							
		12	698	6.43	4600	139.7							
		12	698	6.46	4550	137.2							
12/08/83		12	776	6.7	2300	186.3	94.8	360	5	0.85	3	2.4	250
		12	776	6.68	2250	184.6							
		12	776	6.7	2250	186							
		12	776	6.68	2200	187.4							
05/30/84		12	949	6.6	5280	301							
		12	949	6.58	5250	279							
		12	949	6.54	5300	280							
		12	949	6.55	5300	298							
11/29/84		12	1132	6.82	2900	224	22.9	700					80
		12	1132	6.82	2900	216							
		12	1132	6.82	2900	220							
		12	1132	6.82	2900	219							
03/85		12	1255				22						
07/03/85		12	1349				9.2						
		12	1349				16.8						
11/85		12	1497	6.75	963	180							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
02/86		12	1589	6.54	3045	178							
04/04/86		12	1624						0.022	0.018	0.05	0.07	
		12	1624						0.004	0.001	0.019	0.002	
05/86		12	1681	6.51	3860	180							
08/86		12	1773	6.47	2950	120							
09/22/83	L19	13	698	6.7	10200	38.36	30	3649	7	9.2	1	44	50
		13	698	6.7	10150	39.15							
		13	698	6.7	10500	40.73							
		13	698	6.66	10200	39.15							
12/08/83		13	776	6.6	10000	89.86	23.1	3649	8	3.7	1	11	280
		13	776	6.57	10000	88.89							
		13	776	6.6	10000	91.91							
		13	776	6.58	9800	87.29							
05/30/84		13	949	6.55	13200	34.3							
		13	949	6.6	13200	31.3							
		13	949	6.58	1320	32.1							
		13	949	6.5	13200	32.1							
11/29/84		13	1132	6.69	10000	76.2	61.6	4100					50
		13	1132	6.7	10000	74.6							
		13	1132	6.7	10000	72.9							
		13	1132	6.7	11000	74.7							
11/85		13	1497	6.79	1400	29							
02/86		13	1589	6.55	11490	83							
05/86		13	1681	6.51	12300	23							
08/86		13	1773	6.57	13875	30							
09/22/83	L20	14	698	6.6	9000	34.26	77.8	3299	4	8.9	1.2	39	50
		14	698	6.6	9100	34.98							
		14	698	6.6	9100	34.52							
		14	698	6.68	9000	36.54							
12/08/83		14	776	6.7	12500	96.13	28	4788	174	5.4	2	34	50
		14	776	6.64	13000	97.53							
		14	776	6.65	12500	96.99							
		14	776	6.63	12500	96.41							
05/30/84		14	949	6.55	13300	31.9							
		14	949	6.5	13200	29.7							
		14	949	6.5	13200	29.2							
		14	949	6.54	13300	28.6							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
11/29/84		14	1132	6.71	13000	113	23.1	6150					50
		14	1132	6.71	13000	109							
		14	1132	6.71	13000	107							
		14	1132	6.71	1000	105							
11/85		14	1497	6.78	931	25							
02/86		14	1589	6.48	14540	82							
04/04/86		14	1623						0.063	0.016	0.05	0.2	
		14	1623						0.006	0.001	0.019	0.002	
05/86		14	1681	6.56	14100	22							
08/86		14	1773	6.51	10100	25							
09/22/83	L21	15	698	6.62	8400	33.43	42.6	2775	10	9	1	38	50
		15	698	6.63	8400	36.28							
		15	698	6.63	8400	35.98							
		15	698	6.64	8300	36.67							
12/08/83		15	776	6.71	7000	33.21	23.6	3149	10	2.1	7	8.4	110
		15	776	6.7	7200	32.64							
		15	776	6.7	7000	32.43							
		15	776	6.7	7100	32.62							
05/30/84		15	949	6.63	7700	77.2							
		15	949	6.65	7700	78.1							
		15	949	6.6	7380	73.6							
		15	949	6.65	7700	75.9							
11/29/84		15	1132	6.84	8100	108	36.3	2800					50
		15	1132	6.85	8100	105							
		15	1132	6.85	8100	106							
		15	1132	6.85	8100	105							
11/85		15	1497	6.8	1000	31							
02/86		15	1589	6.6	8000	37							
05/86		15	1681	6.54	8480	25							
08/86		15	1773	6.57	8050	35							
09/22/83	L22	16	698	6.6	4900	46.88	146.7	1359	8	8.9	1.7	38	50
		16	698	6.6	5000	47.19							
		16	698	6.6	5000	47.15							
		16	698	6.64	5000	46.06							
12/08/83		16	776	6.8	6400	40.29	105.2	2399	25	1.5	2	8	110
		16	776	6.74	6200	40.47							
		16	776	6.8	6200	39.72							
		16	776	6.73	6400	40.16							

TABLE B-1 (Cont'd)

Summary of Well Data Used For Statistical Demonstration
Bayou Sorrel, Louisiana

Date	Location	LocaCode	Time	pH	S.C.	TOC	SO4MgpL	ClMgpl	AsUgpL	CdUgpL	CrUgpL	PbUgpL	PhenUgpL
05/30/84		16	949	6.7	7150	79.2							
		16	949	6.68	7150	68.6							
		16	949	6.65	7450	72.5							
		16	949	6.72	7450	64							
11/29/84		16	1132	6.87	7000	96	215.1	2200					50
		16	1132	6.87	7000	92.1							
		16	1132	6.87	7000	91.7							
		16	1132	6.87	7000	92.1							
11/85		16	1497	6.9	1238	41							
02/86		16	1589	6.73	7000	118							
04/04/86		16	1624						0.011	0.01	0.05	0.09	
		16	1624						0.004	0.001	0.019	0.002	
05/86		16	1681	6.56	7030	44							
08/86		16	1773	6.62	6450	42							
11/85	126	18	0	6.89	994	19							
02/86		18	92	6.74	1990	42							
05/86		18	184	6.72	12600	21							
08/86		18	276	6.74	8525	25							

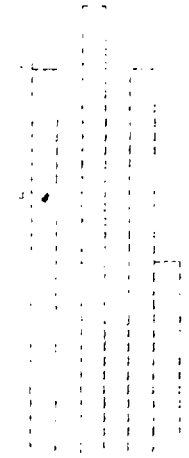

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FIGURE B-1
FREQUENCY DISTRIBUTIONS FOR
HYPOTHETICAL TOC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W O NO	20-08	4/28/87

pool does not show a definable pattern because four quarters of lab replicates are not sufficient to construct a reliable frequency distribution. Data for pH are normally distributed for the entire well field as well as each individual well. Example distributions are shown in Figure B-2; note that pH for Backgrd1 is not normal due to the artificial effects of lab replication.

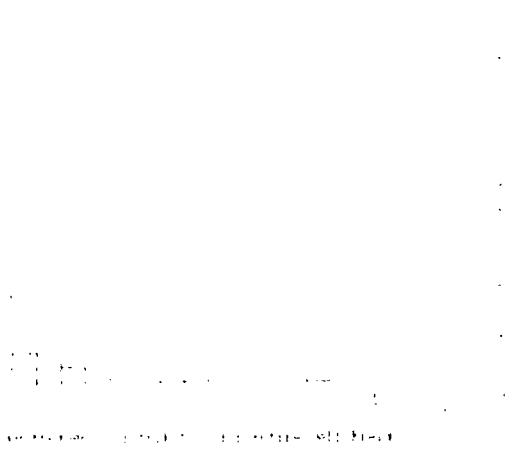
SC data showed a strongly bimodal distribution for both the well field and the composite background data set (Figure B-3). This bimodality had been shown by investigators at the surrogate site to be representative of the opposing influences of Mississippi River dominated ground waters (high conductivity) and rainfall/ swamp dominated (low conductivity) ground waters in the surrogate site region. A similar "gradient" in SC is apparent at the Bayou Sorrel site and is, in fact, the primary reason that the surrogate site was chosen for this demonstration.

The bimodality of the pooled background data for SC is generated by the fact that the two upgradient wells (located on different sides of the surrogate site with respect to the River), although individually normally distributed (Figure B-3), are from different parts of the SC gradient. This "real world" gradient was used to generate a reasonable assignment of surrogate data to Bayou Sorrel well locations by assuming the two upgradient wells were positioned with respect to the North Area facility as illustrated in Figure B-4. Manipulation of the surrogate data then proceeded as follows:

1. The data for the 17 wells were compiled into a summary table and the means were calculated for replicated data (Table B-2). The summary includes a background well pool (variable name = Backgrd1) comprised of four dates of triplicated data from each of the two upgradient wells and a timeline for the summarized data. The four sets of replicated data are from days 698, 776, 949 and 1132 (variable name = TimeBkd1).

2. Replication was removed from all data sets (except Backgrd1) by substituting the means for each date of sample (Table B-3). Means, standard deviation (Std. Dev.), variance (Var) and coefficient of variance (CV) were calculated for the resulting data bases, and the locations were ranked from lowest to highest SC value.

3. The data base was reduced from 17 wells (Tables B-1, B-2 and B-3) to 13 wells (Table B-4), resulting in 11 downgradient wells plus the individual wells for the pooled background data set. The final 13 wells all



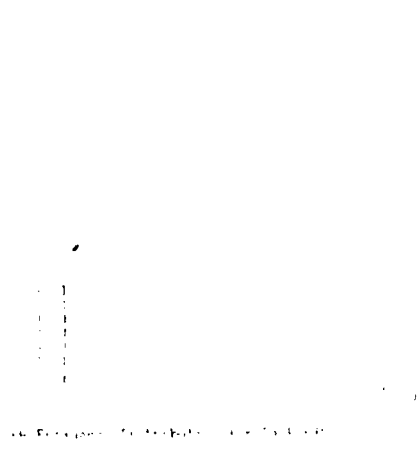


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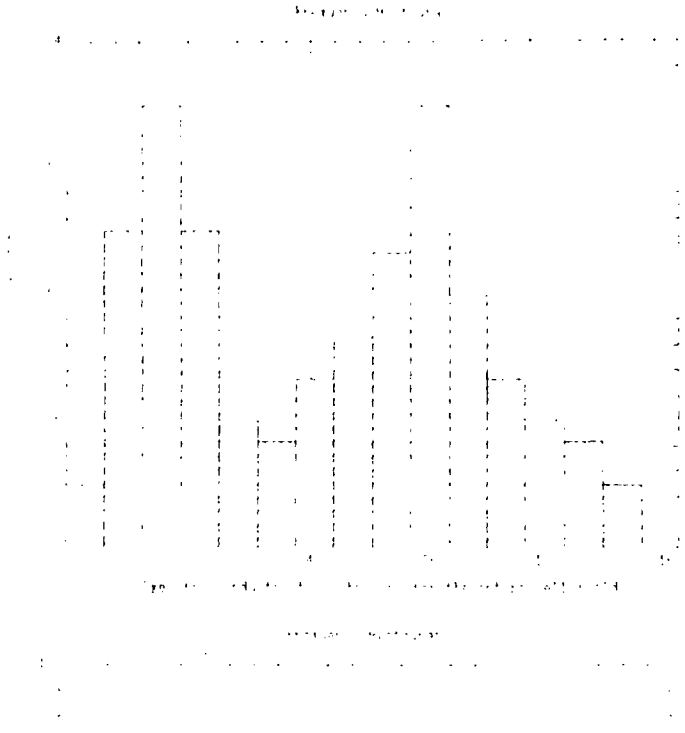
FIGURE B-2
FREQUENCY DISTRIBUTIONS FOR
HYPOTHETICAL pH DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W O NO	20-08	4/28/87



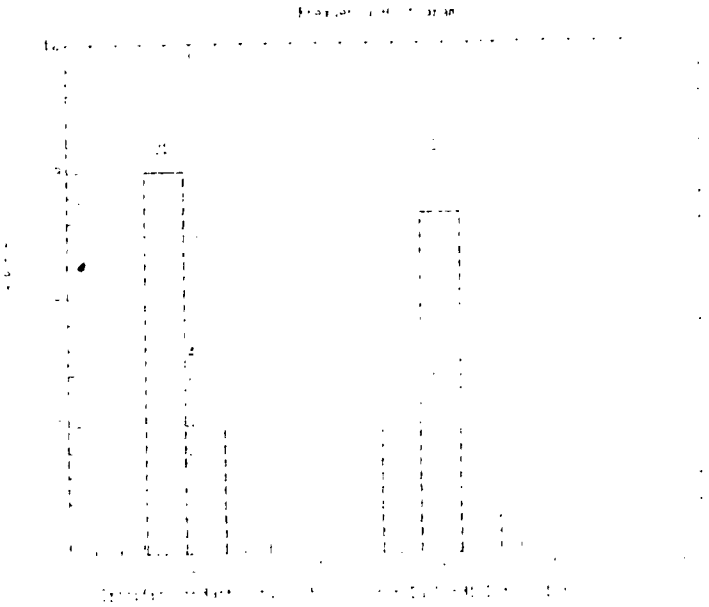


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FIGURE B-3
FREQUENCY DISTRIBUTIONS FOR
HYPOTHETICAL SC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W O NO	20-08	4/28/87

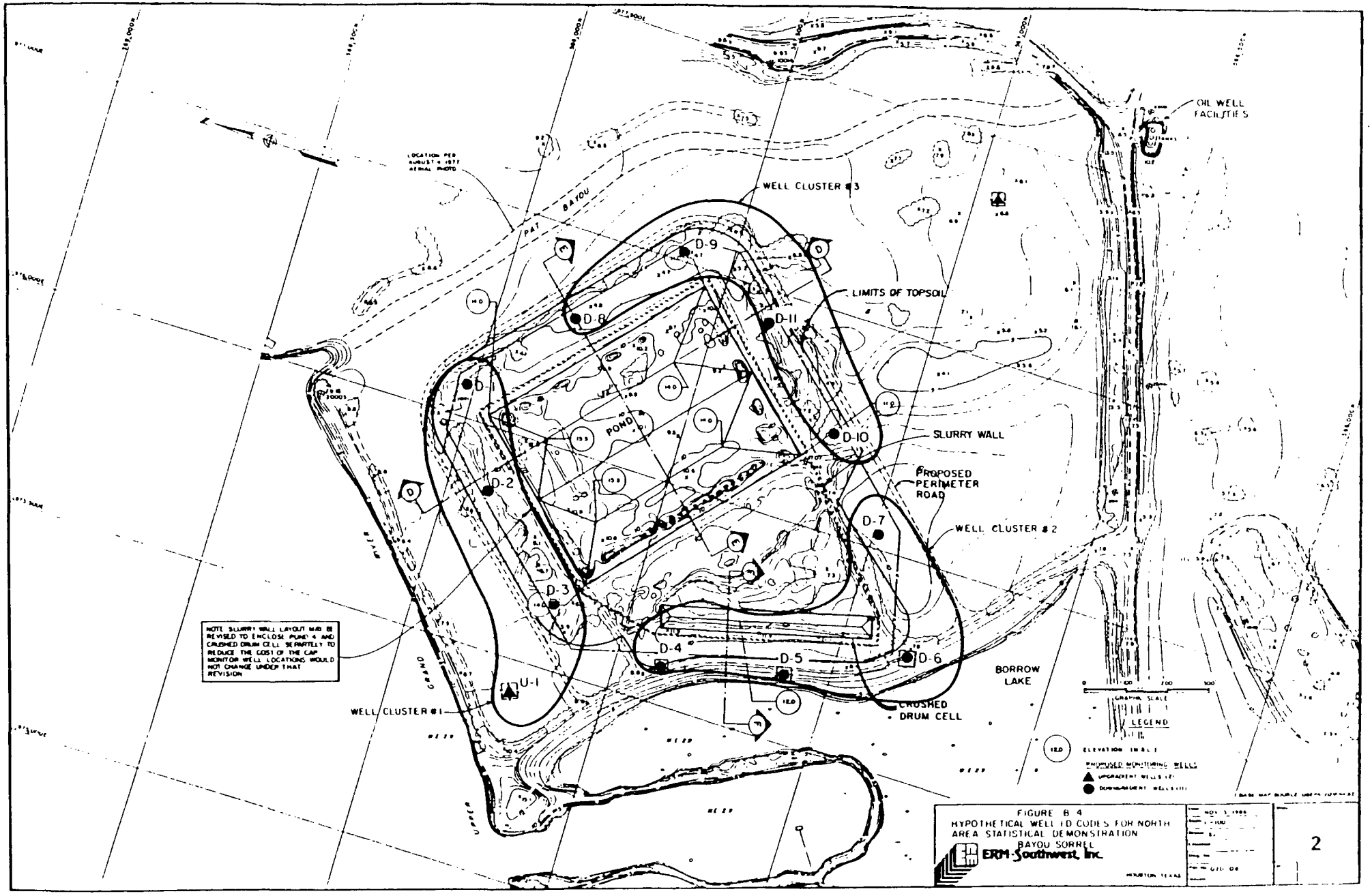

FIGURE B 4
HYPOTHETICAL WELL ID CODES FOR NORTH AREA STATISTICAL DEMONSTRATION
BAYOU SORREL
ERM-Southwest, Inc.

2

TABLE B 2- Summary of Hypothetical Specific Conductivity (SC) Values for the North Landfill

WellName L11toL14			L3	L9	L5	L15	L10	L11	L12	L18	L14	L13	L16	L17	L19	L20	L21	L22	L 6
WellCode Backgrdl Trac0dl Trac1ine			W1	W3	W2	W9	W4	W5	W6	W12	W8	W7	W10	W11	W13	W14	W15	W16	W18
10000	698	1	5900	1540	4900	1310	14200	2500	5700			8000	10700	9000					
10000		195	9100	1130	6900	8490	10490	1640	5400			8300	10100	8400					
10000		276	10600	1140	8100	8000	7000	1640	7400			8900	12700	10300					
10400	776	376	9800		6500	3200	12300	2200	5000	2100	1340	8300	9800	9000					
10000		376										8200	9700	9000					
10950		376										8200	9400	9000					
9100	949	376										8000	9200	8800					
9100		Mean										8175	9525	8950					
9100		446	11000	1300	8400	3600	12500	1700	7200	2100	2400	9600	13400	10300					
8400	1142	446										9700	13450	10150					
8500		446										9500	13200	10000					
8400		446										9450	13000	10400					
2900	698	Mean										9562.5	13412.5	10262.5					
3950		537			9720	3990	12420	1304	7992	3450	9830	10040	14070	10690					
4900		537										9910	14040	10240					
2400	776	537										9990	14060	10300					
2700		537										9990	14050	10540					
2700		Mean										9987.5	14047.5	10457.5					
3400	949	698			9000	4200	12400	1400	8000	4500	2900	10000	12000	11000	10200	9000	8500	4900	
3300		698			8990	4200	12400	1390	9000	4500	3000	10000	12500	11000	10150	9100	8400	5050	
3300		698			9000	4200	12000	1400	8900	4600	3000	10000	12300	11000	10500	9100	8400	5000	
2800	1142	698			9000	4100	12900	1420	8000	4550	3000	9800	12000	11200	10200	9000	8300	5000	
2700		Mean			8975	4225	12700	1402.5	8875	4537.5	2975	9950	12200	11050	10262.5	9050	8375	4975	
2400		776			9000	3750	15000	1350	9000	2300	2700	10300	11800	9000	10000	12500	7000	6400	
		776			9000	3800	15300	1300	9000	2250	2700	10000	11000	10000	10000	13000	7200	6700	
		776			9000	3800	15000	1300	9000	2250	2700	10000	12000	10000	10000	12500	7000	6200	
		776			9000	3800	15200	1300	9200	2200	2650	10000	11700	10000	9000	12500	7100	6400	
		Mean			9025	3787.5	15125	1312.5	9050	2250	2687.5	10075	11625	9950	9950	12625	7075	6400	
		949			11000	3850	15500	1430	8150	5200	3300	9100	11000	11000	13200	13300	7700	7150	
		949			11000	4070	15400	1400	8000	5250	3300	9100	11000	11000	13200	13450	7700	7150	
		949			11000	4070	14950	1430	8000	5300	3300	9100	11000	11000	13200	13200	7300	7450	
		949			10950	4070	15400	1400	8000	5300	3000	9100	11000	11000	13200	13300	7200	7450	
		Mean			10987.5	4015	15262.5	1455	8582.5	5282.5	3245	9107.5	11000	11000	13200	13250	7675	7300	
		1142			11500	4000	15000	1400	7700	2900	2800	8400	12000	9400	10000	13250	8100	7450	
		1142			11000	4000	14500	1400	7800	2900	2700	8500	11000	9000	10000	13250	8100	7800	
		1142			11000	4000	15000	1400	7700	2900	2700	8500	11000	9600	10000	13050	8100	7850	
		1142			11000	4000	14000	1400	7700	2900	2700	8500	11000	9000	11000	13000	8100	7800	
		Mean			11125	4000	14875	1400	7725	2900	2725	8475	11250	9250	10250	13050	8100	7950	
		1497								961	994	1400	1300	1200	1400	931	1000	1201	995
		1589								1045	2940	5400	1400	9875	11450	14250	8650	7000	1950
		1681								3800	3410	11000	13000	11900	12300	14150	8400	7800	12000
		1773								2950	2950	10000	11125	11875	11875	10100	8050	6450	8525

TABLE B 3: Summary of Unreplicated Hypothetical Specific Conductivity (SC) Values for the North Area

WellCode	Backgrd1	TimeBkd1	TimeLine	W1	W3	W2	W9	W4	W5	W6	W12	W8	W7	W10	W11	W13	W14	W15	W16	W18
	10000	698	1	5900	1350	4900	1310	14200	2500	5700			8800	10700	9000					
	10000		195	9100	1130	6900	3600	10900	1640	5500			8300	10100	8400					
	10000		276	10600	1340	8100	3800	7000	1640	7400			8900	12700	10300					
	10300	776	376	9800		6500	3200	12300	2200	5000	2100	1340	8175	9525	8950					
	10000		446	11600	1300	8400	3600	12500	1700	7200	2100	2400	9563	13412	10263					
	10000		537			9720	3990	12420	1304	7992	3450	9830	9987	14048	10457					
	9100	949	698			8975	4225	12700	1402	8875	4537	2975	9950	12200	11050	10263	9050	8375	4975	
	9100		776			9825	3787	15125	1312	9050	2250	2688	10075	11625	9950	9950	12625	7075	6300	
	9100		949			10988	4015	15262	1455	8583	5282	3245	9100	11000	11000	13200	13250	7620	7300	
	8400	1132	1132			11125	4000	14500	1400	7725	2900	2725	8475	11250	9700	10250	13000	8100	7000	
	8500		1497								963	994	1400	1308	1588	1400	931	1000	1230	994
	8500		1589								3045	2940	5600	1460	9875	11490	14540	8000	7000	1930
	2900	698	1681								3860	3410	11000	13000	11900	12300	14100	8400	7030	12600
	3000		1773								2950	2950	10000	13125	11875	13875	10100	8050	6450	8525
	3000																			
	2700	776																		
	2700																			
	2700																			
	3300	949																		
	3300																			
	3300																			
	2800	1132																		
	2700																			
	2700																			
Mean	6170.8			9400.0	1280.0	8543.3	3552.7	12690.7	1655.3	7302.5	3039.7	3227.0	8523.8	10452.4	9593.4	10341.0	10949.5	7087.5	5911.6	6027.3
n	24			5	4	10	10	10	10	10	11	11	14	14	14	8	8	8	8	4
Var	11263025			4695000	10467	4024630	703516	5993556	158156	2106516	1484103	5362954	5846327	16501984	6370331	15132807	19974512	6246043	4101170	30357537
Std Dv.	3356.0			2166.8	102.3	2006.1	838.8	2448.2	397.7	1451.4	1218.2	2315.8	2417.9	4062.3	2524.0	3890.1	4469.3	2499.2	2025.1	5509.8
C V	0.54			0.23	0.08	0.23	0.24	0.19	0.24	0.20	0.40	0.72	0.28	0.39	0.26	0.38	0.41	0.35	0.34	0.91
Rank	8			13	1	12	5	18	2	10	3	4	11	16	14	15	17	9	6	7

TABLE B 4: Summary of Unreplicated Hypothetical Specific Conductivity (SC) Values for the North Area Statistical Demonstration
Final Data Set Structure for Unclustered SC Data

WellCode	Backgrd1	TimeBkd1	Time	D7	D3	D11	D1	D6	D2	U1	U2	D10	D8	D9	D5	D4
	10000	698	1	4900	1310	14200	2500	5700								
	10000	698	195	6900	3600	10900	1640	5500								
	10000	698	276	8100	3800	7000	1640	7400								
	10000	776	376	6400	3200	12300	2200	5000								
	10000	776	446	8400	3600	12500	1700	7200	2100	2400	9563	13412	10263	10600	7725	5975
	10000	776	537	9720	3990	12420	1304	7992	3450	9830	9987	14048	10457	11600	8030	6425
	9100	949	698	8975	4225	12700	1402	8875	4537	2975	9950	12200	11050	10263	8375	4975
	9100	949	776	9825	3787	15125	1312	9050	2250	2688	10075	11625	9950	9950	7075	6300
	9100	949	949	10988	4015	15262	1455	8583	5282	3245	9108	11000	11000	13200	7620	7300
	8400	1132	1132	11125	4000	14500	1400	7725	2900	2725	8475	11250	9700	10250	8100	7000
	8500	1132	1497						963	994	1400	1388	1588	1400	1000	1238
	8500	1132	1589						3045	2940	5600	1460	9875	11490	8000	7000
	2900	698	1681						3860	3410	11000	13000	11900	12300	8400	7030
	3000	698	1773						2950	2950	10000	13125	11875	13875	8050	6450
	3000	698														
	2700	776														
	2700	776														
	2700	776														
	3300	949														
	3300	949														
	3300	949														
	2800	1132														
	2700	1132														
	2700	1132														
Mean	6170.8			8543.3	3552.7	12690.7	1655.3	7302.5	3133.7	3415.7	8515.8	10330.8	9765.8	10492.8	7245.5	5969.3
n	24			10	10	10	10	10	10	10	10	10	10	10	10	10
Var	11263025			4024630	703516	5993556	158156	2106516	1541070	5523632	8401340	23142295	8869724	11927931	4974153	3215833
Std Dv.	3356.0			2006.1	838.8	2448.2	397.7	1451.4	1241.4	2350.2	2898.5	4810.6	2978.2	3453.7	2230.3	1793.3
C V	0.54			0.23	0.24	0.19	0.24	0.20	0.40	0.69	0.34	0.47	0.30	0.33	0.31	0.30
Rank	8			12	5	18	2	10	3	4	11	16	14	15	9	6

have data for at least eight dates of sample, four dates of which are the same as those for Backgrd1. This exercise eliminated wells W1, W3 and W18 (Table B-3) from further analysis. W14, which ranked 17 out of 18, was also eliminated to bring the total down to 13.

4. In order to supply a total of ten dates of sample (four dates to simulate first year quarterly samples, six dates for the first six annual or semiannual monitoring efforts), data from days 1, 195, 276 and 376 were eliminated from W12, W8, W7, W10, and W11 (in Table B-3). Then data were added to W13, W15 and W16 for sample days 446 and 537 to bring the total number of observations for these three wells to 10. (The data added to each well were above the mean for each well for day 446 and below the mean for day 537, a pattern which fits the general pattern for the other wells in the overall data base for those two dates.) Downgradient wells in the restructured data base were then ranked again from lowest to highest and were assigned well codes D1, D2, D3, etc. based on these ranks. The two background wells were designated U1 and U2. The final restructured data base is shown in Table B-4.

5. Downgradient wells were distributed around the perimeter of the North Area based on ranks such that wells with higher SC concentrations are on the U2 side of the facility and those with lower concentrations are on the U1 side of the facility (Figure B-4). This distribution was held constant for all other parameters (in other words, downgradient position was set on the basis of SC concentrations and did not change for analysis of any other parameters considered in this statistical demonstration).

Once the spatial assignment of data to well location was made, downgradient well cluster assignments were made for statistical testing. Because the number of downgradient wells (11) is not an integer multiple of four, it was decided to use one of the upgradient wells as the "12th cell" for the purpose of the demonstration. In the actual monitoring program, the third cluster of four will, instead, include the fourth well from the second cluster. Data for the clusters are summarized in Table B-5.

An important feature of the data structure used for this demonstration is that the designation of background wells was not arbitrary but rather reflects the actual physical relationship of the surrogate site wells to the surrogate site data base. Because a great deal of care was taken to provide for both temporal and spatial continuity between the surrogate-site raw data and the assignment of the reduced data to the final hypothetical well field for the North Area monitoring system, the statistical procedures demonstrated in Section 3 and Attachments C, D and E are based on a valid and reasonable "real world" data base.

TABLE B 5. Comparison of Hypothetical Specific Conductivity (SC) Values for the North Area Statistical Demonstration

SC Conc. Impacted	SC Conc. Background	Well Cluster 1: t 446 days				Well Cluster 2: t 537 days				Well Cluster 3: t 698 days			
698	14000	D1 D4 D8	2400	5975	10263	D1 D4 D8	9830	6425	10457	D1 D4 D8	2975	4975	11050
698	10000	D1 D5 D9	1700	7725	10000	D1 D5 D9	1304	8030	11600	D1 D5 D9	1402	8175	10963
698	10000	D2 D6 D10	2100	7200	13412	D2 D6 D10	3450	7992	14050	D2 D6 D10	4517	8875	17200
776	10000	D3 D7 D11	3600	8400	12500	D3 D7 D11	3990	9720	12420	D3 D7 D11	4225	8975	12470
776	10000	Means	2450.0	7325.0	11693.8	Means	4643.5	8041.0	12131.3	Means	3284.8	7800.0	11556.3
776	10000												
949	9100	Well Cluster 4: t=776 days				Well Cluster 5: t 949 days				Well Cluster 6: t 1132 days			
949	9100												
949	9100	D1 D4 D8	2600	6300	9950	D1 D4 D8	3245	7300	11050	D1 D4 D8	2725	7050	9700
1132	8400	D1 D5 D9	1312	7075	9950	D1 D5 D9	1455	7620	13200	D1 D5 D9	1400	8100	10250
1132	8500	D2 D6 D10	2250	9050	11625	D2 D6 D10	5202	8583	11000	D2 D6 D10	2950	7725	11250
1132	8500	D3 D7 D11	3787	9825	15125	D3 D7 D11	4015	10980	15262	D3 D7 D11	4000	11125	14500
698	2900	Means	2509.3	8062.5	11662.5	Means	3499.3	8622.8	12615.5	Means	2756.3	8487.5	11425.0
698	8000												
698	8000												
776	2700												
776	2700												
776	2700												
949	4000												
949	4000												
949	4000												
1132	2600												
1132	2700												
1132	2700												

ATTACHMENT C

C-1 STATGRAPHICS® Data Entry Formats

C-2 STATGRAPHICS® Code Book Procedures

ATTACHMENT C

C-1 STATGRAPHICS® Data Entry Formats

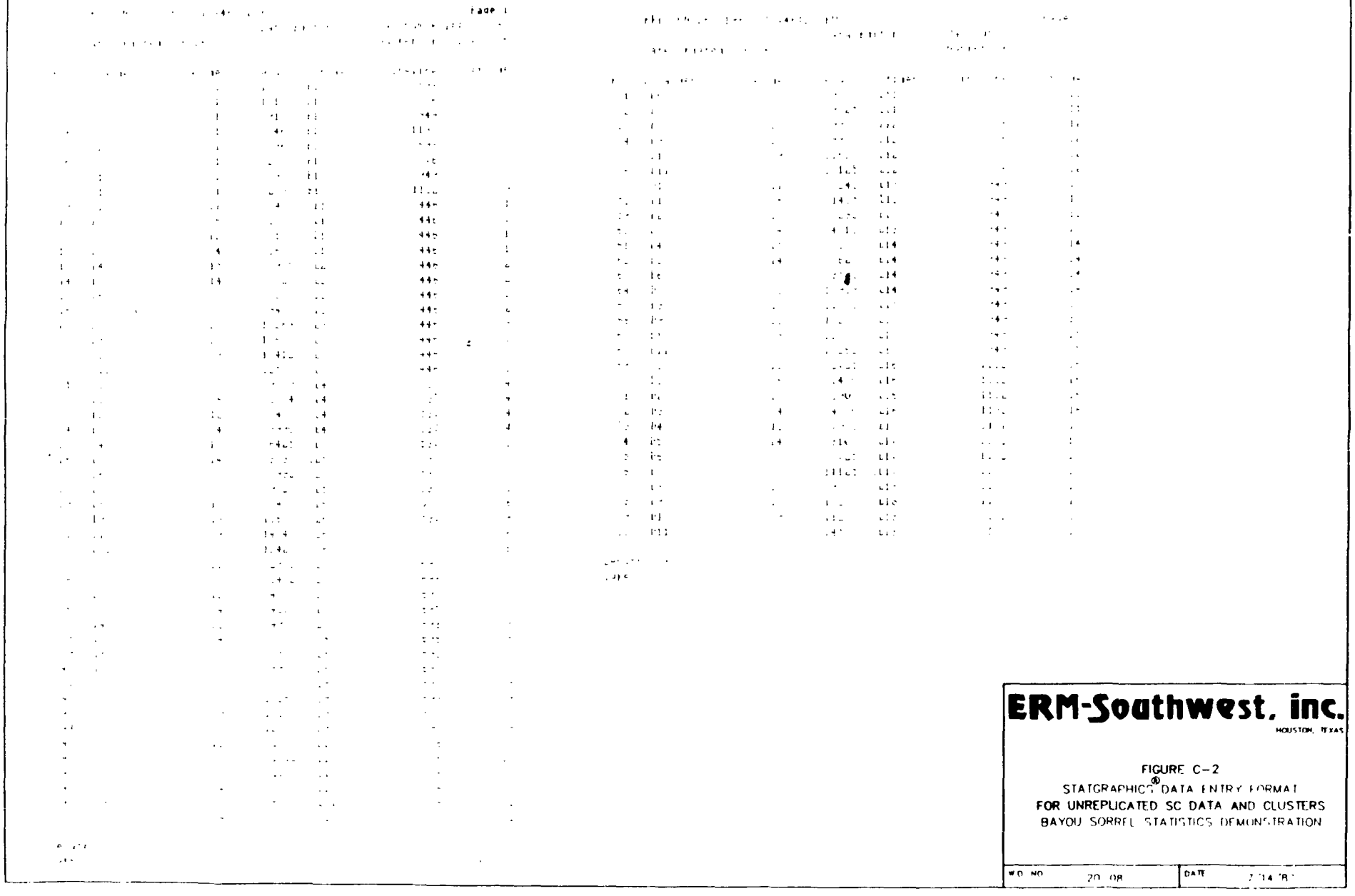

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FIGURE C-2
STATGRAPHICS® DATA ENTRY FORMAT
FOR UNREPLICATED SC DATA AND CLUSTERS
BAYOU SORREL STATISTICS DEMONSTRATION

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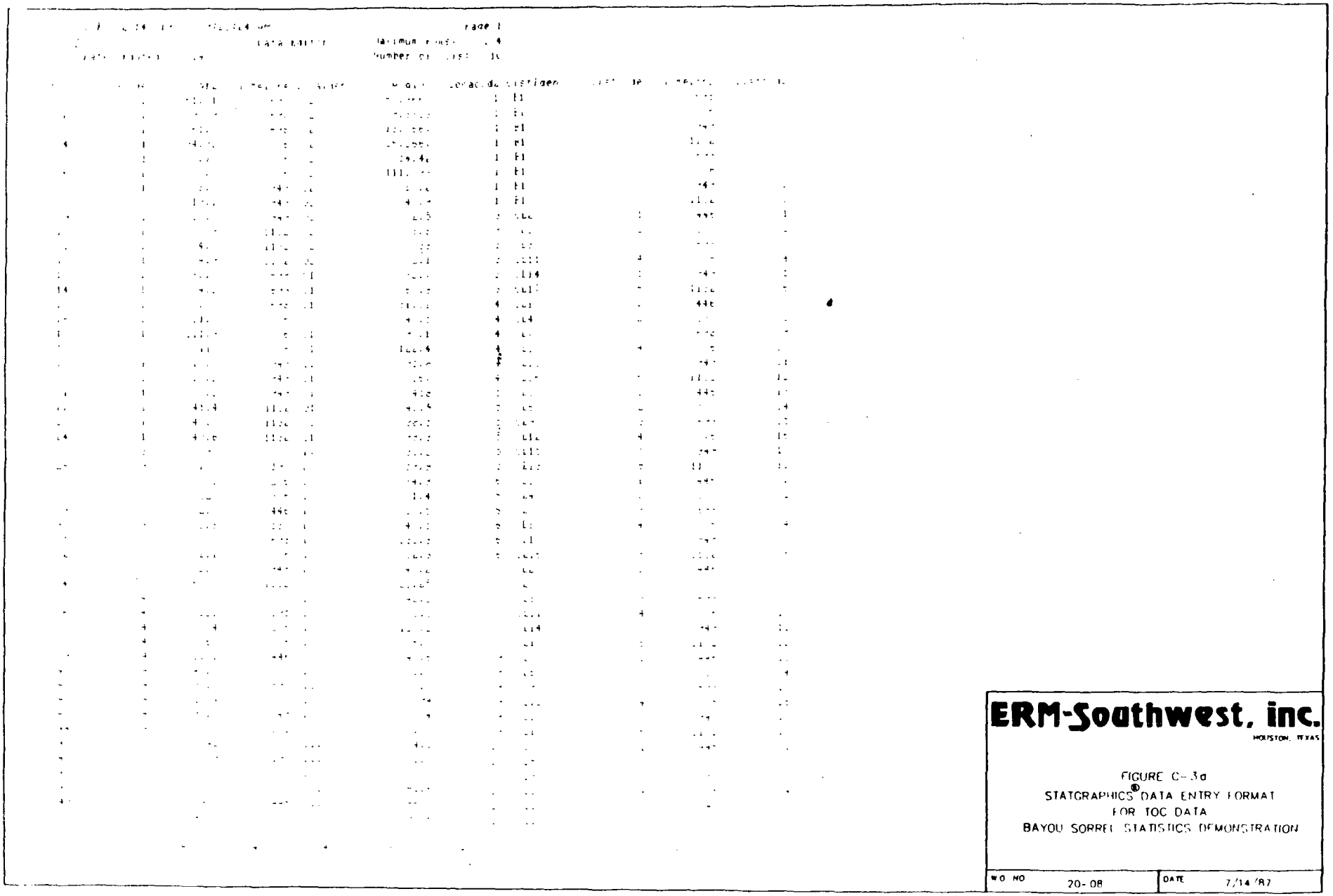

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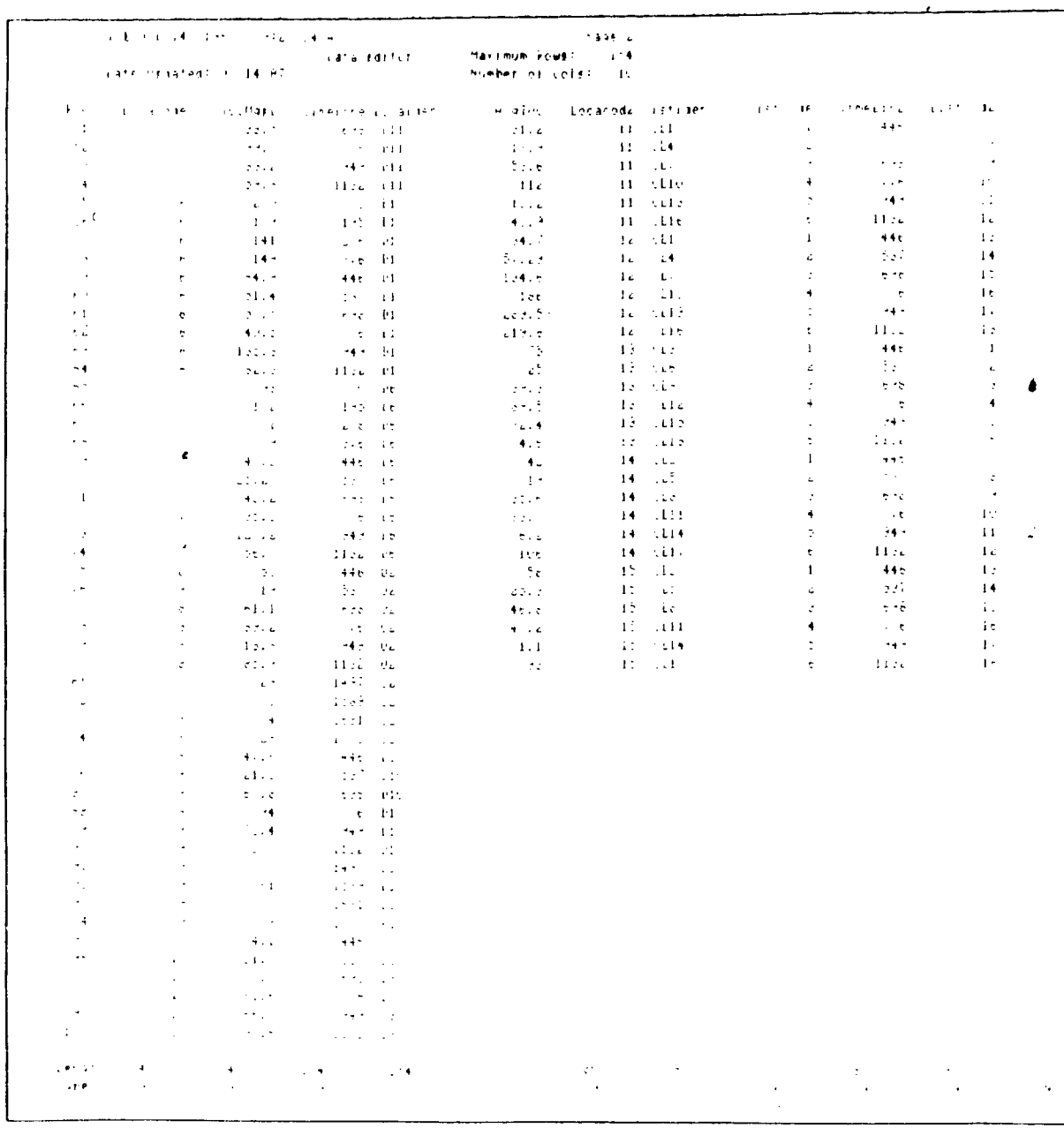
FIGURE C-3a
STATGRAPHICS® DATA ENTRY FORMAT
FOR TOC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO	20-08	DATE	7/14/87



Data Editor

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Number of cells: 15000

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3			33.6	445	C11	5.6	11	C1	3	445		3			
4			27.5	1126	C11	11	11	C11V	4	445		4			
5		1	6.4	1	I1	1.6	11	C11I	1	445		5			
6		1	1.4	145	I1	4.9	11	C11E	2	1126		6			
7		1	141	1	D1	34.7	12	C11	1	446		12			
8		1	144	446	D1	5.6	12	C4	4	547		14			
9		1	44.4	446	D1	134.5	12	C1	2	545		15			
10		1	31.4	21	I1	1ee	12	C11.	4	5		16			
11		0	2.7	445	D1	664.5	12	C113	2	445		1.			
12		0	4.0	5	I1	619.5	12	C11E	5	1126		19			
13		1	1e3.6	445	D1	75	13	C12	1	446		1			
14		1	56.7	1126	D1	25	13	C15	2	5.		2			
15			13	1	D1	25.7	13	C17	2	545		3			
16			1.4	145	I1	5.5	13	C14	4	5		4			
17			6	6.2	I1	24.4	13	C113	1	445		1			
18			4	245	I1	4.5	13	C115	3	1126		3			
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20			1.6	22	I1	1.4	14	C15	2	7.		2			
21			4.12	445	I1	21.4	14	C10	2	545		4			
22		1	25.2	5	I1	21.	14	C111	4	6		10			
23		1	46.16	445	I1	5.2	14	C114	3	445		11			
24		1	35.	1126	I1	195	14	C11.	5	1126		14			
25		1	3.	446	D1	5e	15	C1.	1	446		12			
26		1	1.4	5.	D1	25.2	15	C1	2	225		14			
27		1	61.1	445	D1	45.6	15	C6	2	545		1.			
28		1	27.6	6	D1	4.2	15	C111	4	6		16			
29		1	1e.4	445	D1	1.1	15	C119	1	445		1.			
30		1	25.4	1126	D1	45	15	C1	5	1126		1.			
31			6.4	1445	I1										
32		1	2.	2165	I1										
33		1	4	2221	I1										
34		1	2.7	4	I1										
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36		1	21.2	22	I1										
37		1	5.16	545	D1										
38		1	4	6	D1										
39		1	1.4	445	I1										
40		1	1	21.2	I1										
41		1		247	I1										
42		1	1	2221	I1										
43		1		2221	I1										
44		1		4	I1										
45		1	4.1	445	I1										
46	1	1	21.	22	I1										
47		1	1	22.	I1										
48		1	1.4	6	D1										
49		1	22.	445	I1										
50		1	1.4	445	I1										

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FIGURE C-3b
STATGRAPHICS® DATA ENTRY FORMAT
FOR TOC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO.	20-08	DATE	7/14/87

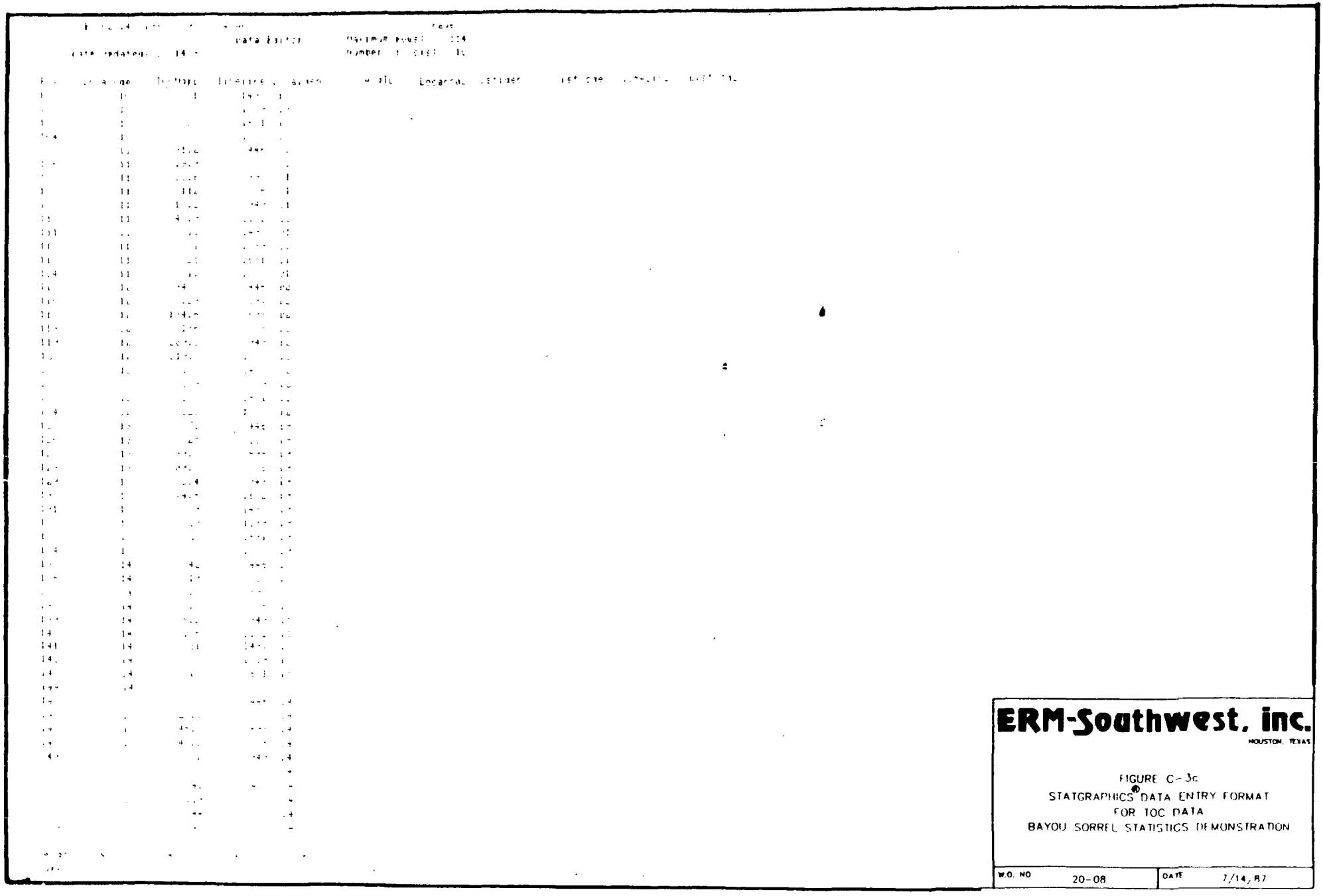

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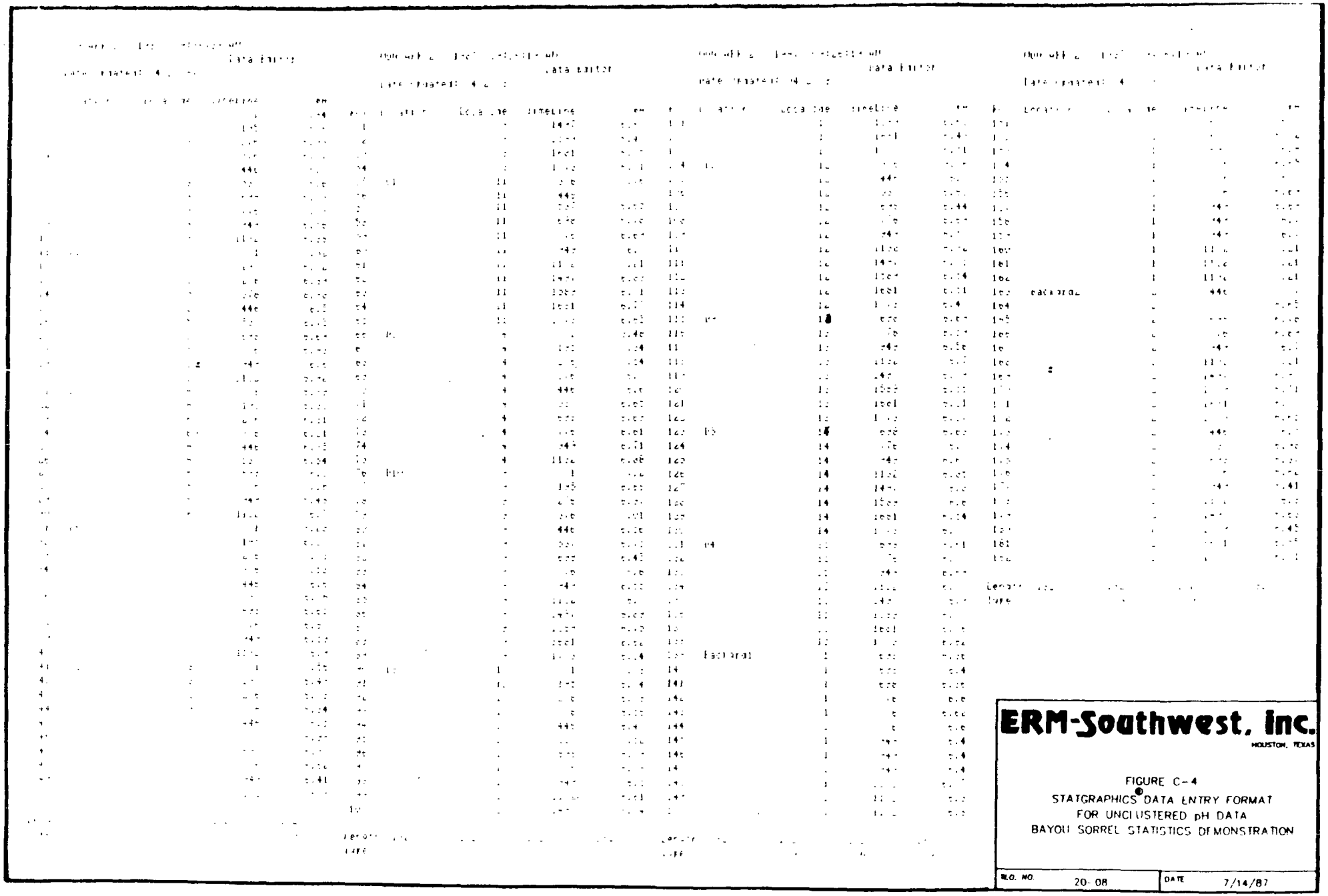
FIGURE C-3c
STATGRAPHICS® DATA ENTRY FORMAT
FOR TOC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO	20-08	DATE	7/14/87



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HOUSTON, TEXAS

FIGURE C-4
STATGRAPHICS® DATA ENTRY FORMAT
FOR UNCLUSTERED pH DATA
BAYOU SORREL STATISTICS DEMONSTRATION

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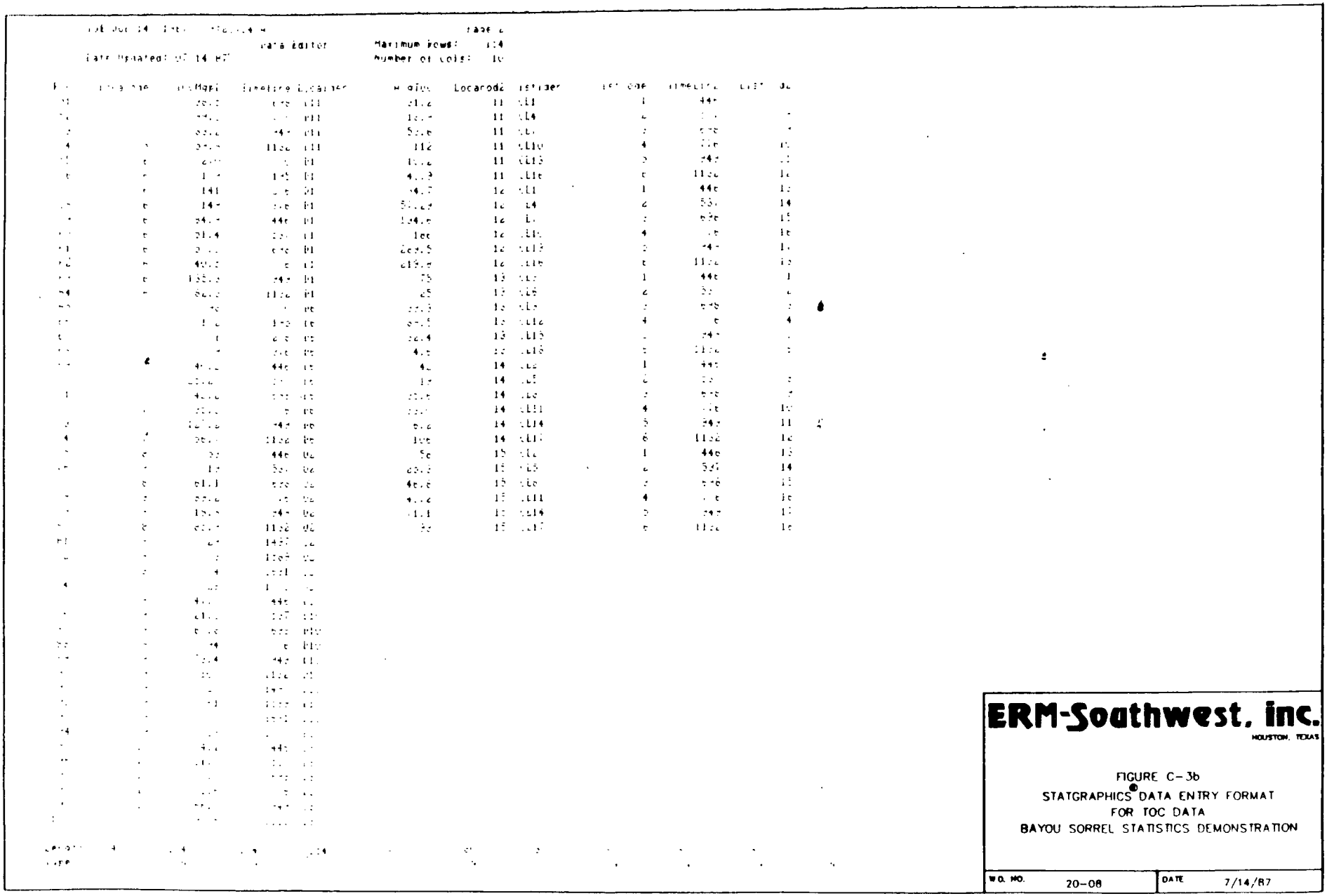

Data Editor

Maximum Rows: 1:4

Number of Cols: 1v

Date Updated: 07 14 87

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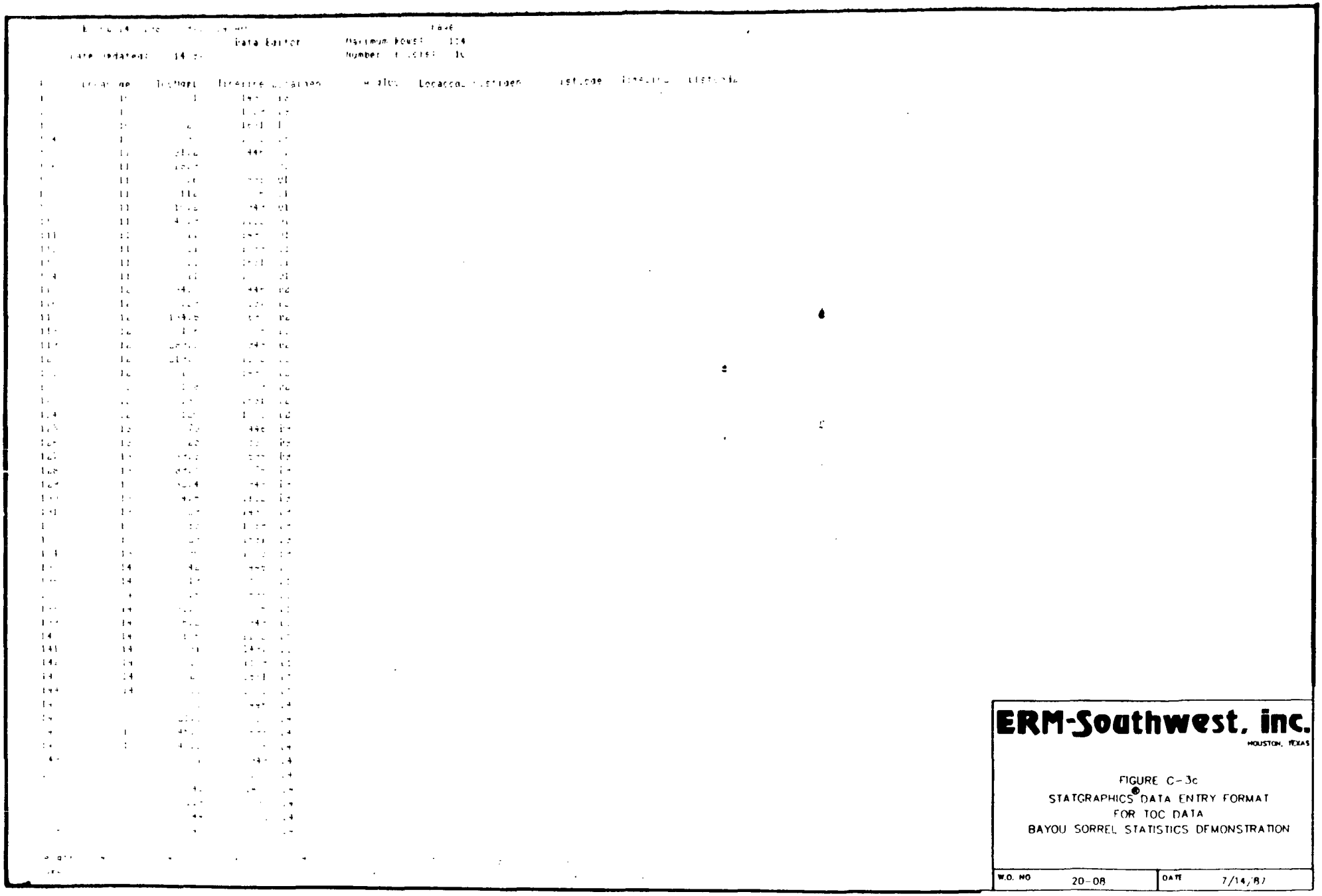
FIGURE C-3b

STATGRAPHICS® DATA ENTRY FORMAT

FOR TOC DATA

BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO.	20-08	DATE	7/14/87



Data Editor

Maximum Rows: 134

Number of Cells: 1K

Date Updated: 14 Jan

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HOUSTON, TEXAS

FIGURE C-3c
STATGRAPHICS® DATA ENTRY FORMAT
FOR TOC DATA
BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO	20-08	DATE	7/14/87

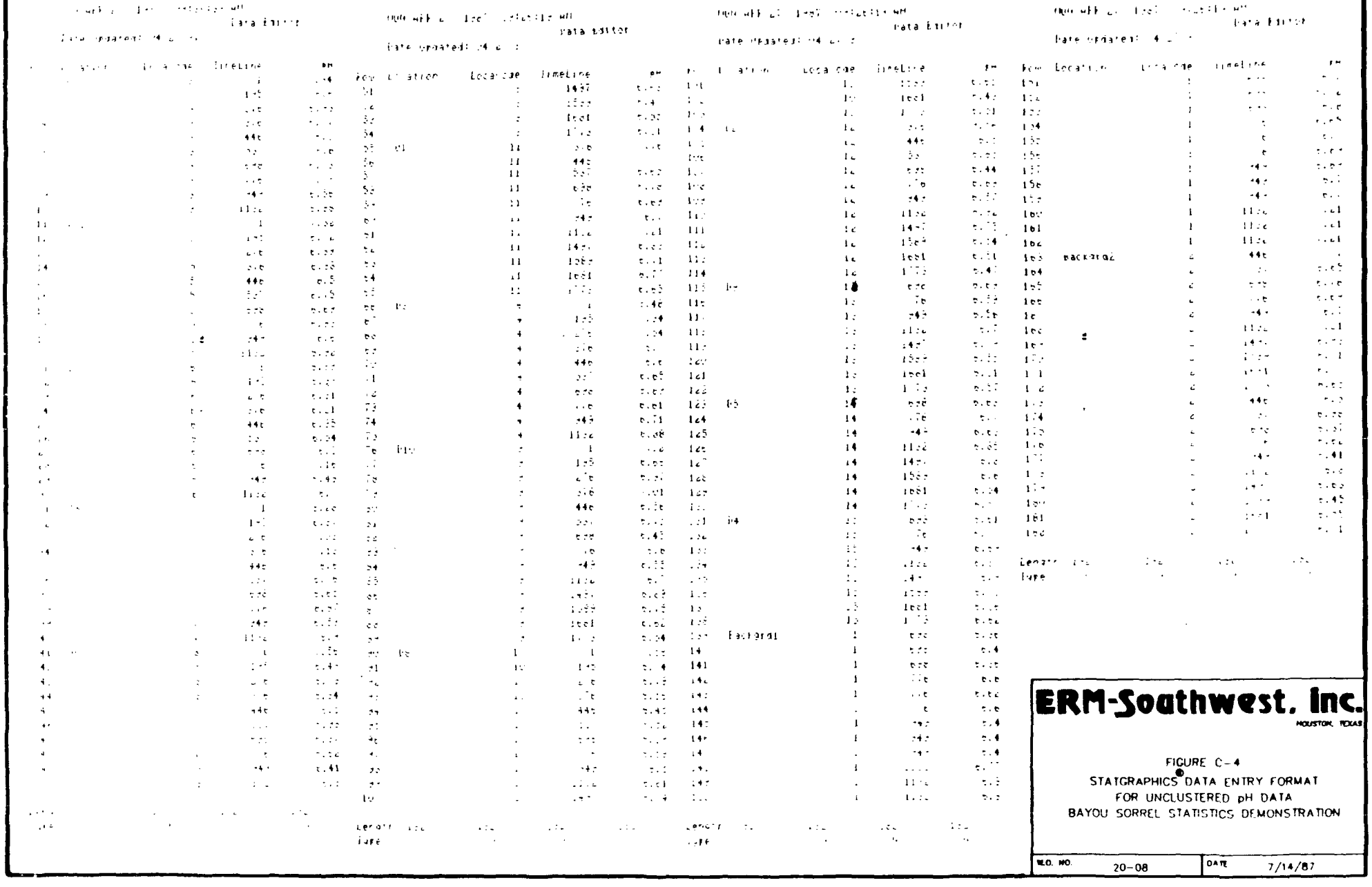

FIGURE C-4
STATGRAPHICS® DATA ENTRY FORMAT
FOR UNCLUSTERED pH DATA
BAYOU SORREL STATISTICS DEMONSTRATION

ERM-Southwest, Inc.
HOUSTON, TEXAS

W.O. NO. 20-08 | DATE 7/14/87

ATTACHMENT C

C-2 STATGRAPHICS® Code Book Procedures

```
ENTER NAME OF RESPONSE VARIABLE:  TOCMgpL
ENTER NAME OF CLASSIFICATION VARIABLE:  LocaCode
Average ranks by level of LocaCode
73.438 87.1 106.05 81.3 113 75 58.2 69.1 70.55 37.9 128.4 61.75 54.15 74.75

Test statistic = 38.656
Significance level  = 2.2688E-4
Press ENTER to continue.
```

```
ENTER NAME OF RESPONSE VARIABLE:  TOCMgpL
ENTER NAME OF CLASSIFICATION VARIABLE:  Timeline
Average ranks by level of Timeline
110.1 123.1 31.4 125.7 81.115 36.577 78.184 105.58 65.632 99.474 44.938 87.563
     48.188 47.438

Test statistic = 55.439
Significance level  = 3.384E-7
Press ENTER to continue.
```

NOTE: If the " Significance Level " is <0.05, a statistically significant difference is indicated. In this example, both well location (LocaCode) and date of sample (Timeline) are significant. This data set uses the replicated background data set.

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FIGURE E-7
RESULTS OF KRUSKAL-WALLIS TEST
FOR TOC-STATGRAPHICS® PROCEDURE
BAYOU SORREL STATISTICS DEMONSTRATION

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```
ENTER NAME OF RESPONSE VARIABLE:  AvgTOC
ENTER NAME OF CLASSIFICATION VARIABLE:  TimeLin2
Average ranks by level of TimeLin2
39.708 15.5 36.821 50.714 43.357 53.214

Test statistic = 21.372
Significance level  = 6.8898E-4
Press ENTER to continue.


ENTER NAME OF RESPONSE VARIABLE:  AvgTOC
ENTER NAME OF CLASSIFICATION VARIABLE:  CListcod2
Average ranks by level of CListcod2
36.688 50.25 15.25 33.625 44.375 46.25 52.25 27.875 12 35 43 47.625 51 41
      19.25 41.5 57.375 56.75 62.25

Test statistic = 26.997
Significance level  = 0.079045
Press ENTER to continue.


ENTER NAME OF RESPONSE VARIABLE:  AvgTOC
ENTER NAME OF CLASSIFICATION VARIABLE:  Locacod2
Average ranks by level of Locacod2
36.688 37.667 59.5 47.667 46.333 30.417 43.5 44.25 24.25 59.333 33.083 30.167
      34.417

Test statistic = 15.963
Significance level  = 0.19292
Press ENTER to continue.
```

NOTE: If the "Significance Level" is <0.05, statistically significant difference is indicated. This example uses the unreplicated background data set. In this example, well location (Locacod2) and date-specific cluster grouping (CListcod2) are not significant, but date of sample (Timelin2) is. Because the variance is not related to well location, statistical testing would be required.

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FIGURE E-8
RESULTS OF KRUSKAL-WALLIS TEST
FOR TOC-STATGRAPHICS® PROCEDURE
BAYOU SORREL STATISTICS DEMONSTRATION

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ATTACHMENT D

Methods, Tables and Examples for Dunnet's Procedure

ATTACHMENT D

Methods, Tables and Examples for Dunnet's Procedure

Dunnet's procedure is a parametric test that can be used to simultaneously compare the sample mean for each well to the sample mean for the "control" (upgradient or background) well(s). Each well that differs significantly from the background data base by a given threshold is declared to be significantly different at a prescribed significance level (0.01 or 0.05). However, except for pH, only positive differences in water quality between up- and downgradient wells are of any regulatory concern. The null hypothesis is that the means of all downgradient wells are equal to the mean for the upgradient data base. The "Alternative Hypothesis" is that the mean for at least one downgradient well is greater than that of the upgradient.

The assumptions required for Dunnet's procedure to be valid are that the samples are independent and that each is a random sample from a normal distribution with a common variance. A common variance and standard deviation are calculated using all data from both the downgradient and upgradient data sets. The comparisons against a single control; the more general case requires use of procedures such as Tukey's or Scheffe's, which are based on the Studentized range and the F-distribution, respectively. Use of the Tukey's and Scheffe's procedure would result in confidence limits that are wider than necessary, a problem which Dunnet's procedure solved.

The mathematical formulas required to perform Dunnet's procedure are summarized in Table D-1. The estimated standard error of the difference in two means is used to calculate the "Allowance" (A) using a T-value obtained from tables developed by Dunnet (1955). Table values are provided here in Table D-2a and D-2b (for one-sided limits) and Tables D-2c and D-2d (for two-sided limits) and represent a multivariate analogue of the Student's t-distribution. An allowance "A" can be calculated as follows for equal sample sizes:

$$A = \pm Tc(Sc)\ (SQRT(1/N_B + 1/N_M))$$

where Tc = critical point
Sc = common standard deviation
N_B = number of observations for background well
N_M = number of observations for a downgradient well
SQRT - square root

TABLE D-1

Summary of Mathematics Needed for Dunnet's Procedure

---

w = total number of downgradient wells
Nw = number of observations per well
x = value of observation for individual wells
Xw = mean of the x-values for individual wells
Vw = variance of values for individual wells
= (SUM(x-Xw))/(Nw-1)
Sw = standard deviation = SQRT of Vw
SSw = sum of squares of x-values for each w
Sx = sum of x-values
SxS = Sx squared

GENERAL CASE (Equal or Unequal sample size)

Vc = common variance = (SUM(SSw) - (SUM((SxS)/Nw)))/d.f.
Sc = common standard deviation = SQRT of Vc
d.f. = SUM(Nw)-(w+1)
Tm = test statistic calcualted as
Tm = (Xm - Xb)/(Sc*(SQRT(1/Nb + 1/Nm)))
where Nb = no. of obsrvs. for background Well B
Nm = no. of obsrvs. for monitoring Well M
and Xm = mean of obsrvs. for monitoring Well M
Xb = mean of obsrvs. for background Well B

Tc = critical point (from Tables C-1a through C-1d)

Notes: Format used for this summary follow LOTUS 1-2-3 nomenclature for special functions

SQRT = square root
* = multiply
sum = add
/ = divide
- = subtract

TABLE D-2a. To one-sided comparisons, P=.05, (w=no. of downgradient wells.

d.f\w	1	2	3	4	5	6	7	8	9
5	2.02	2.44	2.68	2.85	2.98	3.08	3.16	3.24	3.30
6	1.94	2.34	2.56	2.71	2.83	2.92	3.00	3.07	3.12
7	1.89	2.27	2.48	2.62	2.73	2.82	2.89	2.95	3.01
8	1.86	2.22	2.42	2.55	2.66	2.74	2.81	2.87	2.92
9	1.83	2.18	2.37	2.50	2.60	2.68	2.75	2.81	2.86
10	1.81	2.15	2.34	2.47	2.56	2.64	2.70	2.76	2.81
11	1.80	2.13	2.31	2.44	2.53	2.60	2.67	2.72	2.77
12	1.78	2.11	2.29	2.41	2.50	2.58	2.64	2.69	2.74
13	1.77	2.09	2.27	2.39	2.48	2.55	2.61	2.66	2.71
14	1.76	2.08	2.25	2.37	2.46	2.53	2.59	2.64	2.69
15	1.75	2.07	2.24	2.36	2.44	2.51	2.57	2.62	2.67
16	1.75	2.06	2.23	2.34	2.43	2.50	2.56	2.61	2.65
17	1.74	2.05	2.22	2.33	2.42	2.49	2.54	2.59	2.64
18	1.73	2.04	2.21	2.32	2.41	2.48	2.53	2.58	2.62
19	1.73	2.03	2.20	2.31	2.40	2.47	2.52	2.57	2.61
20	1.72	2.03	2.19	2.30	2.39	2.46	2.51	2.56	2.60
24	1.71	2.01	2.17	2.28	2.36	2.43	2.48	2.53	2.57
30	1.70	1.99	2.15	2.25	2.33	2.40	2.45	2.50	2.54
40	1.68	1.97	2.13	2.23	2.31	2.37	2.42	2.47	2.51
60	1.67	1.95	2.10	2.21	2.28	2.35	2.39	2.44	2.48
120	1.66	1.93	2.08	2.18	2.26	2.32	2.37	2.41	2.45
inf.	1.64	1.92	2.06	2.16	2.23	2.29	2.34	2.38	2.42

TABLE 5-2b. To one-sided comparisons, P=.01. (w=no. of downgradient wells)

d.f.w	1	2	3	4	5	6	7	8	9
5	3.37	3.90	4.21	4.43	4.60	4.73	4.85	4.94	5.03
6	3.14	3.61	3.88	4.07	4.21	4.33	4.43	4.51	4.59
7	3.00	3.42	3.66	3.83	3.96	4.07	4.15	4.23	4.30
8	2.90	3.29	3.51	3.67	3.79	3.88	3.96	4.03	4.09
9	2.82	3.19	3.40	3.55	3.66	3.75	3.82	3.89	3.94
10	2.76	3.11	3.31	3.45	3.56	3.64	3.71	3.78	3.83
11	2.72	3.06	3.25	3.28	3.48	3.56	3.63	3.69	3.74
12	2.68	3.01	3.19	3.32	3.42	3.50	3.56	3.62	3.67
13	2.65	2.97	3.15	3.27	3.37	3.44	3.51	3.56	3.61
14	2.62	2.94	3.11	3.23	3.32	3.40	3.46	3.51	3.56
15	2.60	2.91	3.08	3.20	3.29	3.36	3.42	3.47	3.52
16	2.58	2.88	3.05	3.17	3.26	3.33	3.39	3.44	3.48
17	2.57	2.86	3.03	3.14	3.23	3.30	3.36	3.41	3.45
18	2.55	2.84	3.01	3.12	3.21	3.27	3.33	3.38	3.42
19	2.54	2.83	2.99	3.10	3.18	3.25	3.31	3.36	3.40
20	2.53	2.81	2.97	3.08	3.17	3.23	3.29	3.34	3.38
24	2.49	2.77	2.92	3.03	3.11	3.17	3.22	3.27	3.31
30	2.46	2.72	2.87	2.97	3.05	3.11	3.16	3.21	3.24
40	2.42	2.68	2.82	2.92	2.99	3.05	3.10	3.14	3.18
60	2.39	2.64	2.78	2.87	2.94	3.00	3.04	3.08	3.12
120	2.36	2.60	2.73	2.82	2.89	2.94	2.99	3.03	3.06
inf.	2.33	2.56	2.68	2.77	2.84	2.89	2.93	2.97	3.00

TABLE D-[illegible]. To two-sided comparisons, P=.05, (w=no. of downgradient wells)

d.f.\w	1	2	3	4	5	6	7	8	9
5	2.57	3.03	3.29	3.48	3.62	3.73	3.82	3.90	3.97
6	2.45	2.86	3.10	3.26	3.39	3.49	3.57	3.64	3.71
7	2.36	2.75	2.97	3.12	3.24	3.33	3.41	3.47	3.53
8	2.31	2.67	2.88	3.02	3.13	3.22	3.29	3.35	3.41
9	2.26	2.61	2.81	2.95	3.05	3.14	3.20	3.26	3.32
10	2.23	2.57	2.76	2.89	2.99	3.07	3.14	3.19	3.24
11	2.20	2.53	2.72	2.84	2.94	3.02	3.08	3.14	3.19
12	2.18	2.50	2.68	2.81	2.90	2.98	3.04	3.09	3.14
13	2.16	2.48	2.65	2.78	2.87	2.94	3.00	3.06	3.10
14	2.14	2.46	2.63	2.75	2.84	2.91	2.97	3.02	3.07
15	2.13	2.44	2.61	2.73	2.82	2.89	2.95	3.00	3.04
16	2.12	2.42	2.59	2.71	2.80	2.87	2.92	2.97	3.02
17	2.11	2.41	2.58	2.69	2.78	2.85	2.90	2.95	3.00
18	2.10	2.40	2.56	2.68	2.76	2.83	2.89	2.94	2.98
19	2.09	2.39	2.55	2.66	2.75	2.81	2.87	2.92	2.96
20	2.09	2.38	2.54	2.65	2.73	2.80	2.86	2.90	2.95
24	2.06	2.35	2.51	2.61	2.70	2.76	2.81	2.86	2.90
30	2.04	2.32	2.47	2.58	2.66	2.72	2.77	2.82	2.86
40	2.02	2.29	2.44	2.54	2.62	2.68	2.73	2.77	2.81
60	2.00	2.27	2.41	2.51	2.58	2.64	2.69	2.73	2.77
120	1.98	2.24	2.38	2.47	2.55	2.60	2.65	2.69	2.73
inf.	1.96	2.21	2.35	2.44	2.51	2.57	2.61	2.65	2.69

TABLE D-2d. To two-sided comparisons, P=.01, (W=no. of downgradient wells

d.f\W	1	2	3	4	5	6	7	8	9
5	4.03	4.63	4.98	5.22	5.41	5.56	5.69	5.80	5.89
6	3.71	4.21	4.51	4.71	4.87	5.00	5.10	5.20	5.28
7	3.50	3.95	4.21	4.39	4.53	4.64	4.74	4.82	4.89
8	3.36	3.77	4.00	4.17	4.29	4.40	4.48	4.56	4.62
9	3.25	3.63	3.85	4.01	4.12	4.22	4.30	4.37	4.43
10	3.17	3.53	3.74	3.88	3.99	4.08	4.16	4.22	4.28
11	3.11	3.45	3.65	3.70	3.89	3.98	4.05	4.11	4.16
12	3.05	3.39	3.58	3.71	3.81	3.89	3.96	4.02	4.07
13	3.01	3.33	3.52	3.65	3.74	3.82	3.89	3.94	3.99
14	2.98	3.29	3.47	3.59	3.69	3.76	3.83	3.88	3.93
15	2.95	3.25	3.43	3.55	3.64	3.71	3.78	3.83	3.88
16	2.92	3.22	3.39	3.51	3.60	3.67	3.73	3.78	3.83
17	2.90	3.19	3.36	3.47	3.56	3.63	3.69	3.74	3.79
18	2.88	3.17	3.33	3.44	3.53	3.60	3.66	3.71	3.75
19	2.86	3.15	3.31	3.42	3.50	3.57	3.63	3.68	3.72
20	2.85	3.13	3.29	3.40	3.48	3.55	3.60	3.65	3.69
24	2.80	3.07	3.22	3.32	3.40	3.47	3.52	3.57	3.61
30	2.75	3.01	3.15	3.25	3.33	3.39	3.44	3.49	3.52
40	2.70	2.95	3.09	3.19	3.26	3.32	3.37	3.41	3.44
60	2.66	2.90	3.03	3.12	3.19	3.25	3.29	3.33	3.37
120	2.62	2.85	2.97	3.06	3.12	3.18	3.22	3.26	3.29
inf.	2.58	2.79	2.92	3.00	3.06	3.11	3.15	3.19	3.22

If the difference between the background mean (X_B) and any downgradient well mean (X_M) is greater than the allowance A, failure(s) would be indicated. Dunnet, 1964 gives a method for adjusting critical points (i.e., T-values) for unequal sample sizes and unequal variance for two-sided comparisons.

In practice, use of the procedure may be summarized by the following equation which is used to calculate a sample T_M for the equal sample size case:

$$T_M = \frac{X_M - X_B}{S_c(\text{SQRT } 2/n)}$$

For unequal samples sizes, T_M becomes:

$$T_M = \frac{X_M - X_B}{S_c(\text{SQRT}[\text{SUM}(1/N_B + 1/N_M)])}$$

The value of T_M is then compared to T_C, which is found in the tables by entering at the column corresponding to w (the number of downgradient wells) and the row corresponding to d.f. (degrees of freedom), calculated as $\text{SUM}(N_w)-(w + 1)$.

Dunnet (1955) stated that optimum sample size is achieved when the ratio of the number of control samples (N_B) the number of samples per treatment (N_W) is approximately equal to the square root of W (for confidence coefficients of 0.95 or greater).

For example, if there are a total of nine downgradient wells in the monitoring system (w = 9), three times as many samples should be taken from the background well as from each of the downgradient wells. Therefore, if n = 4 for each of the downgradient wells, then n = 12 for the upgradient wells.

EXAMPLES FOR BAYOU SORREL DEMONSTRATION

Table B-5, Attachment B, presents a summary of well clusters created from the "Year 2-7" data base to simulate clustering of downgradient wells at the Bayou Sorrel site of the North Area. As discussed in Attachment B, for the purposes of this demonstration, data from U1 was used to make up the "12th well". During actual monitoring at the site, the first well of the third cluster will be the fourth well from the second cluster. If a gradient in SC is found similar to that generated in the hypothetical data base used to perform this demonstration, wells may be clustered on the basis of SC rankings prior to statistical testing of indicator parameters.

Table D-3 (a through f) presents the results of testing the "Year 2-7" clusters against Backgrd1. "Clust1" is the cluster set for the first year of the series, corresponding to day 446; "Clust2" corresponds to day 537, and so forth. "WelClst1" is comprised of wells U1, D1, D2 and D3 (See Table B-5, Attachment B); WelClst2 = D4, D5, D6, and D7; and WelClst3 = D8, D9, D10, and D11. WelClst3 is significantly higher in SC than the other clusters for all six dates of sample.

Table D-3a: Bayou Corne Demonstration: Hypothetical Clustered SC Data for the North Area

DATA FOR PARAMETER A = SC Clust1, Backgrd

(Notes)	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
x1	10000	2400	5975	10263
x2	10000	1700	7725	10000
x3	10000	2100	7200	12412
x4	10300	3600	8400	12500
x5	10000			
x6	10000			
x7	9100			
x8	9100			
x9	9100			
x10	8400			
x11	8500			
x12	8500			
x13	2900			
x14	3000			
x15	3000			
x16	2700			
x17	2700			
x18	2700			
x19	3300			
x20	3300			
x21	3300			
x22	2800			
x23	2700			
x24	2700			

CALCULATIONS

Descriptive statistics for individual wells

(Notes)	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
Nw	24	4	4	4
Xw	6170.8	2450.0	7325.0	11643.8
Vw	1.13E+07	6.70E+05	1.05E+06	2.18E+06
Sw	3356.0	818.5	1025.3	1510.6
SSw	1.17E+09	2.60E+07	2.10E+08	5.54E+08
Sx	14e100	9e00	29300	46775
SxS	2.19E+10	9.60E+07	8.58E+08	2.19E+09
SxS/Nw	9.14E+08	2.40E+07	2.15E+08	5.47E+08
CVw	0.54	0.33	0.14	0.13

DUNNET's Procedure statistics

w	3
d.f.	22
Vc	8.47E+06
Sc	2910.43

Background = Well 0, therefore Xb = 6171

Let Well M = Well 1; Xm = 2450

and Xm-Xb = -3721

Tm = -2.37 ++++++

Let Well M = Well 2; Xm = 7325

and Xm-Xb = 1154

Tm = 0.73 .

Let Well M = Well 3; Xm = 11644

and Xm-Xb = 5472

Tm = 3.51 ++++++

To (.05) 2.15 (one-sided comparison)

To (.01) 2.87 (one-sided comparison)

To (.05) 2.47 (two-sided comparison)

To (.01) 3.15 (two-sided comparison)

"." means non-significant at the 0.05 level

"++++++" means significant at the 0.05 level

See Tables D-3a, D-3b, D-3c and D-3d for critical values of T (To)

Table 3-13: Bayou Sorrel Demonstration: Hypothetical Clustered 3D Data for the North Area

DATA FOR PARAMETER A = SC Clust2, Backgrd

(Notes)	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
x1	10000	9830	6425	10457
x2	10000	1204	8030	11600
x3	10000	3450	7992	14048
x4	10200	3990	9720	12420
x5	10000			
x6	10000			
x7	9100			
x8	9100			
x9	9100			
x10	8400			
x11	8500			
x12	8500			
x13	2900			
x14	3000			
x15	3000			
x16	2700			
x17	2700			
x18	2700			
x19	3100			
x20	3300			
x21	3300			
x22	2300			
x23	2700			
x24	2700			

CALCULATIONS

Descriptive statistics for individual wells

(Notes)	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
Nw	24	4	4	4
Xw	6170.8	4643.5	8041.8	12131.3
Vw	1.13E+07	1.33E+07	1.91E+06	2.28E+06
Sw	3356.9	3647.1	1345.7	1510.2
SSw	1.17E+09	1.26E+08	2.64E+08	5.06E+08
Sx	148100	18574	32167	48502
SxS	2.19E+10	2.45E+08	1.03E+09	2.35E+09
SxS/Nw	9.14E+08	8.62E+07	2.59E+08	5.89E+08
CVw	0.54	0.79	0.17	0.12

DUNNETT's Procedure statistics

w	3
d.f.	32
Vc	9.73E+06
Sc	3119.54

Background = Well 0, therefore Xb = 6171

Let Well M = Well 1: Xa = 4644
and Xa-Xb = -1527
Ta = -0.91 .

Let Well M = Well 2: Xa = 8042
and Xa-Xb = 1871
Ta = 1.11 .

Let Well M = Well 3: Xa = 12131
and Xa-Xb = 5960
Ta = 3.54 ******

To (.05) 2.15 (one-sided comparison)
To (.01) 2.87 (one-sided comparison)
To (.05) 2.47 (two-sided comparison)
To (.01) 3.15 (two-sided comparison)

"." means non-significant at the 0.05 level
"******" means significant at the 0.05 level

See Tables 3-13, 3-14, 3-15 and 3-16
for critical values of T To:

TABLE D-1c: Bayou Sorrel Demonstration: Hypothetical Clustered SC Data for the North Area

DATA FOR PARAMETER A = SC Clust3, Backgrd1

(Notes)	Well 0 Backgrd1	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
x1	10000	2975	4975	11050
x2	10000	1402	8375	10263
x3	10000	4537	8875	12200
x4	10300	4225	8975	12700
x5	10000			
x6	10000			
x7	9100			
x8	9100			
x9	9100			
x10	8400			
x11	8500			
x12	8500			
x13	2900			
x14	3000			
x15	3000			
x16	2700			
x17	2700			
x18	2700			
x19	3300			
x20	3320			
x21	3300			
x22	2800			
x23	2700			
x24	2700			

CALCULATIONS

Descriptive statistics for individual wells

(Notes)	Well 0 Backgrd1	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
Nw	24	4	4	4
Xw	6170.8	3284.8	7800.0	11553.3
Vw	1.13E+07	2.03E+06	3.62E+06	1.22E+06
Sw	3356.0	1425.1	1901.5	1103.2
SSw	1.17E+09	4.93E+07	2.54E+08	5.38E+08
Sx	148100	13109	31200	-6213
SxS	2.19E+10	1.72E+08	9.72E+08	2.14E+09
SxS/Nw	9.14E+08	4.32E+07	2.43E+08	5.34E+08
CVw	0.54	0.43	0.24	0.10

DUNNET's Procedure statistics

w	3
d.f.	32
Vc	8.74E+06
Sc	2956.14

Background = Well 0, therefore Xb = 6171

Let Well M = Well 1; Xm = 3285
and Xm-Xb = -2886
Tm = -1.31 .

Let Well M = Well 2; Xm = 7800
and Xm-Xb = 1629
Tm = 1.02 .

Let Well M = Well 3; Xm = 11553
and Xm-Xb = 5382
Tm = 3.37 ******

Tc (.05) 2.15 (one-sided comparison)
Tc (.01) 2.87 (one-sided comparison)
Tc (.05) 2.47 (two-sided comparison)
Tc (.01) 3.15 (two-sided comparison)

"." means non-significant at the 0.05 level
"******" means significant at the 0.05 level

See Tables D-3a, D-3b, D-3c and D-3d
for critical values of T (Tc)

TABLE D-2a: Bayou Sorrel Demonstration: Hypothetical Clustered SC Data for the North Area

DATA FOR PARAMETER A = SC Clust4, Backgrd

[Notes]	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
x1	10000	2688	6300	9950
x2	10000	1312	7075	9950
x3	10000	2250	9050	11625
x4	10300	3787	9825	15125
x5	10000			
x6	10000			
x7	9100			
x8	9100			
x9	9100			
x10	8400			
x11	8500			
x12	8500			
x13	2900			
x14	3000			
x15	3000			
x16	2700			
x17	2700			
x18	2700			
x19	3300			
x20	3300			
x21	3300			
x22	2800			
x23	2700			
x24	2720			

CALCULATIONS

Descriptive statistics for individual wells

[Notes]	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
Nw	24	4	4	4
Xw	6170.8	2509.3	8062.5	11602.5
Vw	1.13E+07	1.06E+06	2.72E+06	5.95E+06
Sw	3356.0	1027.2	1649.6	2439.6
SSw	1.17E+09	2.84E+07	2.68E+08	5.62E+08
Sx	148100	10037	32250	46010
SxS	2.19E+10	1.01E+08	1.04E+09	2.18E+09
SxS/Nw	9.14E+08	2.52E+07	2.60E+08	5.44E+08
CVw	0.54	0.41	0.20	0.21

DUNNET's Procedure statistics

w	3
d.f.	32
Vc	9.01E+06
Sc	3001.22

Background = Well 0, therefore Xb = 6171

Let Well M = Well 1; Xm = 2509

and Xm-Xb = -3662

Tm = -2.26 ++++++

Let Well M = Well 2; Xm = 8063

and Xm-Xb = 1892

Tm = 1.17 .

Let Well M = Well 3; Xm = 11603

and Xm-Xb = 5432

Tm = 3.39 ++++++

Tc (.05) 2.15 (one-sided comparison)

Tc (.01) 2.87 (one-sided comparison)

Tc (.05) 2.47 (two-sided comparison)

Tc (.01) 3.15 (two-sided comparison)

"." means non-significant at 0.05 level

"++++++" means significant at 0.05 level

See Tables D-2a, D-2b, D-2c and D-2d for critical values of T (Tc)

Table D-1a: Bayou Corrie Demonstration: Hypothetical Clustered SC Data for the North Area

DATA FOR PARAMETER A = SC Clust5, Backgrd

(Notes)	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
x1	10000	3245	7300	11000
x2	10000	1455	7620	13200
x3	10000	5282	8583	11000
x4	10300	4015	10988	15262
x5	10000			
x6	10000			
x7	9100			
x8	9100			
x9	9100			
x10	8400			
x11	8500			
x12	8500			
x13	2900			
x14	3000			
x15	3000			
x16	2700			
x17	2700			
x18	2700			
x19	3300			
x20	3300			
x21	3300			
x22	2800			
x23	2700			
x24	2700			

CALCULATIONS

Descriptive statistics for individual wells

(Notes)	Well 0 Backgrd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
Nw	24	4	4	4
Xw	6170.8	3499.3	8622.3	12515.5
Vw	1.13E+07	2.56E+06	2.78E+06	4.19E+06
Sw	3356.0	1600.8	1668.4	2046.6
SSw	1.17E+09	5.67E+07	3.06E+08	6.49E+08
Sx	148100	13997	34491	50402
SxS	2.19E+10	1.96E+08	1.19E+09	2.55E+09
SxS/Nw	9.14E+08	4.90E+07	2.97E+08	6.37E+08
CVw	0.54	0.46	0.19	0.16

DUNNET's Procedure statistics

w	3
d.f.	32
Vc	8.99E+06
Sc	2998.20

Background = Well 0, therefore Xb = 6171

Let Well M = Well 1: Xm = 3499

and Xm-Xb = -2672

Tm = -1.65 .

Let Well M = Well 2: Xm = 8622

and Xm-Xb = 2452

Tm = 1.51 .

Let Well M = Well 3: Xm = 12516

and Xm-Xb = 6345

Tm = 3.98 ******

Tc (.05) 2.15 (one-sided comparison)

Tc (.01) 2.87 (one-sided comparison)

Tc (.05) 2.47 (two-sided comparison)

Tc (.01) 3.15 (two-sided comparison)

"." means non-significant at the 0.05 level

"******" means significant at the 0.05 level

See Tables D-2a, D-2b, D-2c and D-2d for critical values of T (Tc)

TABLE D-3f: Bayou Sorrel Demonstration: Hypothetical Clustered SC Data for the North Area

DATA FOR PARAMETER A = SC Clustb, Backgrnl

(Notes)	Well 0 Backgrnd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
x1	10000	2725	7000	9700
x2	10000	1400	8100	10250
x3	10000	2900	7725	11250
x4	10300	4000	11125	14500
x5	10000			
x6	10000			
x7	9100			
x8	9100			
x9	9100			
x10	8400			
x11	8500			
x12	8500			
x13	2900			
x14	3000			
x15	3000			
x16	2700			
x17	2700			
x18	2700			
x19	3300			
x20	3300			
x21	3300			
x22	2900			
x23	2700			
x24	2720			

CALCULATIONS

Descriptive statistics for individual wells

(Notes)	Well 0 Backgrnd	Well 1 WellClst1	Well 2 WellClst2	Well 3 WellClst3
Nw	24	4	4	4
Xw	6170.8	2756.3	8467.5	11425.0
Vw	1.13E+07	1.14E+06	3.10E+06	4.81E+06
Sw	3356.0	1065.8	1761.6	2193.1
SSw	1.17E+09	3.38E+07	2.98E+08	5.36E+08
Sx	148100	11025	33950	45700
SxS	2.19E+10	1.22E+08	1.15E+09	2.09E+09
SxS/Nw	9.14E+08	3.04E+07	2.88E+08	5.22E+08
CVw	0.54	0.39	0.21	0.19

DUNNET's Procedure statistics

w	3
d.f.	32
Vc	8.34E+06
Sc	2990.61

Background = Well 0, therefore Xb = 6171

Let Well M = Well 1; Xa = 2756

and Xa-Xb = -3415

Ta = -2.11 .

Let Well M = Well 2; Xa = 8467

and Xa-Xb = 2297

Ta = 1.43 .

Let Well M = Well 3; Xa = 11425

and Xa-Xb = 5254

Ta = 3.25 ++++++

Tc (.05) 2.15 (one-sided comparison)

Tc (.01) 2.87 (one-sided comparison)

Tc (.05) 2.47 (two-sided comparison)

Tc (.01) 3.15 (two-sided comparison)

"." means non-significant at the 0.05 level

"++++++" means significant at the 0.05 level

See Tables D-3a, D-3b, D-3c and D-3d
for critical values of T Tc

ATTACHMENT E

Methods and Tables for Non-Parametric Tests:
Kruskal-Wallis and Mann-Whitney-Wilcoxon Tests

E-1: Mathematics of Kruskal-Wallis and Mann-Whitney-Wilcoxon Tests

E-2: STRAGRAPHICS^{R} Results for Kruskal-Wallis Tests for TOC and pH Data (See Section 3 for SC Results)

E-3: STRAGRAPHICS^{R} Results for Mann-Whitney-Wilcoxon Tests for SC Data

ATTACHMENT E

Section E-1: Mathematics of Kruskal-Wallis and Mann-Whitney-Wilcoxon Tests

FIGURE **E** – 2

Rank Sum Test for Two Samples

17-4 THE RANK-SUM TEST

In Example 17-4 we counted the number of runs in the arrangement of 20 observations, 10 from each of two populations. Another statistic which may be used to compare the two samples is the *rank-sum statistic* T'', defined as follows. Arrange the two samples together in order of size and assign rank scores to the individual observations, score 1 to the smallest, score 2 to the second smallest, and so on. Then T'' is the sum of ranks of the observations in the smaller of the two samples. If the samples are of the same size we may choose either sample. Note that if T'' is the sum of the N_1 ranks for samples of sizes N_1 and N_2, respectively, then T'' can be as small as $1 + 2 + 3 + \cdots + N_1 = N_1(N_1 + 1)/2$ or as large as $N_1(2N_2 + N_1 + 1)/2$.

In Table A-20 we have recorded some of the percentiles of the sampling distribution of T'' in the case where the two samples are from populations having identical distributions. We reject the hypothesis that we have random samples from identically distributed populations if T'' is significantly large or significantly small.

For example, if $N_1 = N_2 = 10$ we see from Table A-20 that the chance that T'' is less than or equal to 79 is .026 and the chance that T'' is greater than or equal to 131 is .026. Thus values of $T'' \leq 79$ and $T'' \geq 131$ form a 5.2 per cent critical region for the above hypothesis. In Example 17-4 the ranks of the A sample are 2, 3, 5, 6, 10, 11, 12, 15, 17, 18, and so $T'' = 99$; since this is not in the critical region, we accept the hypothesis that we have random samples from identically distributed populations.

In the case of ties we replace the observation by the mean of the ranks for which it is tied.

Normal approximation. For N_1 and N_2 both larger than 10 we use the fact that the sampling distribution of T'' is approximately normal with mean and variance

$$\mu_{T''} = \frac{N_1(N_1 + N_2 + 1)}{2} \quad \text{and} \quad \sigma_{T''}^2 = \frac{N_1 N_2(N_1 + N_2 + 1)}{12}$$

Source: Dixon and Massey 1969

and obtain the approximate chance that T'' will be less than or equal to T_0'' by finding the area to the left of $z = (T_0'' - \mu_{T''} + \frac{1}{2})/\sigma_{T''}$ from Table A-1. For the preceding example, where $N_1 = N_2 = 10$, these formulas give $\mu_{T''} = 105$ and $\sigma_{T''} = \sqrt{175} = 13.2$. The observed value of $T'' = 99$ gives a z score of $z = -5.5/13.2 = -.42$, and this, if compared with $z_{.025} = -1.96$ and $z_{.975} = 1.96$, is seen to be not significant at the 5 per cent level. Since the exact distribution of T'' is given for $N_1 = N_2 = 10$, we can compare the normal approximation with the exact chance that T'' will be less than or equal to 99. The exact chance is .312. The normal approximation read from Table A-1 for $z = -.42$ gives the approximate chance .337. Also note that for $T_0'' = 79$, $z = (79 - 105 + \frac{1}{2})/13.2 = -1.93$, which gives the approximate chance .027 corresponding to the exact chance .026.

The rank-sum test requires approximately 5 per cent more observations than a t test to provide the same power as a t test for shifts in means of two normally distributed populations. For nonnormal populations the rank-sum test may be more powerful than the t test. In some cases the rank-sum test requires only 80 per cent as many observations for equal power. It should be noted that for nonnormal populations Table V.5 does not apply to the distribution of t, whereas the distribution of T'' in Table A-20 may be used whether or not the populations are normal.

Rank-sum test for several samples. Ranks can be used to test the hypothesis that k samples of sizes $n_1, n_2, \ldots, n_k$ are randomly drawn from k identically distributed populations. We arrange the $N = \Sigma n_i$ observations together in order of size and assign ranks as was done for the two-sample rank-sum test. Let R_i be the sum of ranks of the ith sample, and let

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

If the hypothesis is true and the n_i's are not small, the sampling distribution of the statistic H is approximately χ^2 with $k - 1$ degrees of freedom. If all n_i's are greater than 5, the 90th and 99th percentiles in Table V.4 are reasonably accurate. In the case of ties we replace the observation by the mean of the ranks for which it is tied. The statistic H is essentially the variance of the sample rank sums R_i. If a significantly large value of H is observed the hypothesis is rejected.

T'_s	$T'_{1-\alpha}$	α
(6,10) (Cont.)		
48	54	396
49	53	437
50	52	479
51	51	521
	(7,7)	
28	77	000
29	76	001
30	75	001
31	74	002
32	73	003
33	72	006
34	71	009
35	70	013
36	69	019
37	68	027
38	67	036
39	66	049
40	65	064
41	64	082
42	63	104
43	62	130
44	61	159
45	60	191
46	59	228
47	58	267
48	57	310
49	56	355
50	55	402
51	54	451
52	53	500
	(7,8)	
28	84	000
29	83	000
30	82	001
31	81	001
32	80	002
33	79	003
34	78	005
35	77	007
36	76	010
37	75	014
38	74	020
39	73	027
40	72	036
41	71	047
42	70	060
43	69	076
44	68	095
45	67	116

T'_s	$T'_{1-\alpha}$	α
(7,8) (Cont.)		
46	66	140
47	65	168
48	64	198
49	63	232
50	62	268
51	61	306
52	60	347
53	59	389
54	58	433
55	57	478
56	56	522
	(7,9)	
28	91	000
29	90	000
30	89	000
31	88	001
32	87	001
33	86	002
34	85	003
35	84	004
36	83	006
37	82	008
38	81	011
39	80	016
40	79	021
41	78	027
42	77	036
43	76	045
44	75	057
45	74	071
46	73	087
47	72	105
48	71	126
49	70	150
50	69	175
51	68	204
52	67	235
53	66	268
54	65	303
55	64	340
56	63	379
57	62	419
58	61	459
59	60	500
	(7,10)	
28	98	000
29	97	000
30	96	000
31	95	000

T'_s	$T'_{1-\alpha}$	α
(7,10) (Cont.)		
32	94	001
33	93	001
34	92	001
35	91	002
36	90	003
37	89	005
38	88	007
39	87	009
40	86	012
41	85	017
42	84	022
43	83	028
44	82	035
45	81	044
46	80	054
47	79	065
48	78	081
49	77	097
50	76	116
51	75	135
52	74	157
53	73	182
54	72	209
55	71	237
56	70	268
57	69	300
58	68	335
59	67	370
60	66	406
61	65	443
62	64	481
63	63	519
	(8,8)	
36	100	000
37	99	000
38	98	000
39	97	001
40	96	001
41	95	001
42	94	002
43	93	003
44	92	005
45	91	007
46	90	010
47	89	014
48	88	019
49	87	025
50	86	032
51	85	041

T'_s	$T'_{1-\alpha}$	α
(8,8) (Cont.)		
52	84	052
53	83	065
54	82	080
55	81	097
56	80	117
57	79	139
58	78	164
59	77	191
60	76	221
61	75	253
62	74	287
63	73	323
64	72	360
65	71	399
66	70	439
67	69	480
68	68	520
	(8,9)	
36	108	000
40	104	000
41	103	001
42	102	001
43	101	002
44	100	003
45	99	004
46	98	006
47	97	008
48	96	010
49	95	014
50	94	018
51	93	023
52	92	030
53	91	037
54	90	046
55	89	057
56	88	069
57	87	084
58	86	100
59	85	118
60	84	138
61	83	161
62	82	185
63	81	212
64	80	240
65	79	271
66	78	303
67	77	336
68	76	371
69	75	407

T'_s	$T'_{1-\alpha}$	α
(8,9) (Cont.)		
70	74	444
71	73	481
72	72	519
	(8,10)	
36	116	000
41	111	000
42	110	001
43	109	001
44	108	002
45	107	002
46	106	003
47	105	004
48	104	006
49	103	008
50	102	010
51	101	013
52	100	017
53	99	022
54	98	027
55	97	034
56	96	042
57	95	051
58	94	061
59	93	073
60	92	086
61	91	102
62	90	118
63	89	137
64	88	158
65	87	180
66	86	204
67	85	230
68	84	257
69	83	286
70	82	317
71	81	348
72	80	381
73	79	414
74	78	448
75	77	483
76	76	517

T'_s	$T'_{1-\alpha}$	α
(9,9)		
45	126	000
50	121	000
51	120	001
52	119	001
53	118	001
54	117	002
55	116	003
56	115	004
57	114	005
58	113	007
59	112	009
60	111	012
61	110	016
62	109	020
63	108	025
64	107	031
65	106	039
66	105	047
67	104	057
68	103	068
69	102	081
70	101	095
71	100	111
72	99	129
73	98	149
74	97	170
75	96	193
76	95	218
77	94	245
78	93	273
79	92	302
80	91	333
81	90	365
82	89	398
83	88	432
84	87	466
85	86	500
	(9,10)	
45	135	000
52	128	000
53	127	001

T'_s	$T'_{1-\alpha}$	α
(9,10) (Cont.)		
54	126	001
55	125	001
56	124	002
57	123	003
58	122	004
59	121	005
60	120	007
61	119	009
62	118	011
63	117	014
64	116	017
65	115	022
66	114	027
67	113	033
68	112	039
69	111	047
70	110	056
71	109	067
72	108	078
73	107	091
74	106	106
75	105	121
76	104	139
77	103	158
78	102	178
79	101	200
80	100	223
81	99	248
82	98	274
83	97	302
84	96	330
85	95	360
86	94	390
87	93	421
88	92	452
89	91	484
90	90	516
	(10,10)	
55	155	000
63	147	000
64	146	001

T'_s	$T'_{1-\alpha}$	α
(10,10) (Cont.)		
65	145	001
66	144	001
67	143	001
68	142	002
69	141	003
70	140	003
71	139	004
72	138	006
73	137	007
74	136	009
75	135	012
76	134	014
77	133	018
78	132	022
79	131	026
80	130	032
81	129	038
82	128	045
83	127	053
84	126	062
85	125	072
86	124	083
87	123	095
88	122	109
89	121	124
90	120	140
91	119	157
92	118	176
93	117	197
94	116	218
95	115	241
96	114	264
97	113	289
98	112	315
99	111	342
100	110	370
101	109	398
102	108	427
103	107	456
104	106	485
105	105	515

For sample sizes greater than 10 the chance that the statistic T' will be less than or equal to an integer k is given approximately by the area under the standard normal curve to the left of

$$z = \frac{k - \frac{1}{2} - N_1(N_1 + N_2 + 1)/2}{\sqrt{N_1 N_2 (N_1 + N_2 + 1)/12}}$$

Source: Dixon and Massey, 1969

The values of T_L, $T_{1-\alpha}$ and α are such that if the N_1 and N_2 observations are chosen at random from the same popular on the chance that the rank sum T' of the N_1 observations in the smaller sample is equal to or less than T_L is α and the chance that T' is equal to or greater than $T_{1-\alpha}$ is α. The sample sizes are shown in parentheses (N_1, N_2)

T_L	$T_{1-\alpha}$	α
	(1,1)	
1	3	.500
	(1,2)	
1	4	.333
2	2	.667
	(1,3)	
1	4	.250
2	3	.500
	(1,4)	
1	5	.200
2	4	.400
3	3	.600
	(1,5)	
1	6	.167
2	5	.333
3	4	.500
	(1,6)	
1	7	.143
2	6	.286
3	5	.428
4	4	.571
	(1,7)	
1	8	.125
2	7	.250
3	6	.375
4	5	.500
	(1,8)	
1	9	.111
2	8	.222
3	7	.333
4	6	.444
5	5	.556
	(1,9)	
1	10	.100
2	9	.200
3	8	.300
4	7	.400
5	6	.500
	(1,10)	
1	11	.091
2	10	.182
3	9	.273
4	8	.364
5	7	.455
6	6	.545

T_L	$T_{1-\alpha}$	α
	(2,2)	
3	7	.167
4	6	.333
5	5	.667
	(2,3)	
3	9	.100
4	8	.200
5	7	.400
6	6	.600
	(2,4)	
3	11	.067
4	10	.133
5	9	.267
6	8	.400
7	7	.600
	(2,5)	
3	13	.047
4	12	.095
5	11	.190
6	10	.286
7	9	.429
8	8	.571
	(2,6)	
3	15	.036
4	14	.071
5	13	.143
6	12	.214
7	11	.321
8	10	.429
9	9	.571
	(2,7)	
3	17	.028
4	16	.056
5	15	.111
6	14	.167
7	13	.250
8	12	.333
9	11	.444
10	10	.556
	(2,8)	
3	19	.022
4	18	.044
5	17	.089
6	16	.133
7	15	.200

T_L	$T_{1-\alpha}$	α
	(2,9)	
3	21	.067
4	20	.133
5	19	.267
6	18	.356
7	17	.556
8	16	.644
9	15	.733
10	14	.867
11	13	.933
	(2,10)	
3	23	.045
4	22	.091
5	21	.182
6	20	.273
7	19	.364
8	18	.455
9	17	.545
10	16	.636
11	15	.727
12	14	.818
13	13	.909
	(3,3)	
6	15	.050
7	14	.100
8	13	.200
9	12	.350
10	11	.500
	(3,4)	
6	18	.028
7	17	.057
8	16	.114
9	15	.200
10	14	.314
11	13	.429
12	12	.571
	(3,5)	
6	21	.018
7	20	.036

T_L	$T_{1-\alpha}$	α
	(3,5) (Cont.)	
8	19	.071
9	18	.125
10	17	.196
11	16	.286
12	15	.393
13	14	.500
	(3,6)	
6	24	.012
7	23	.024
8	22	.048
9	21	.083
10	20	.131
11	19	.190
12	18	.274
13	17	.357
14	16	.452
15	15	.548
	(3,7)	
6	27	.008
7	26	.017
8	25	.033
9	24	.058
10	23	.092
11	22	.133
12	21	.192
13	20	.258
14	19	.333
15	18	.417
16	17	.500
	(3,8)	
6	30	.006
7	29	.012
8	28	.024
9	27	.042
10	26	.067
11	25	.097
12	24	.139
13	23	.188
14	22	.248
15	21	.315
16	20	.387
17	19	.461
18	18	.539

T_L	$T_{1-\alpha}$	α
	(3,9)	
6	33	.005
7	32	.009
8	31	.015
9	30	.032
10	29	.050
11	28	.073
12	27	.105
13	26	.141
14	25	.186
15	24	.241
16	23	.300
17	22	.363
18	21	.432
19	20	.500
	(3,10)	
6	36	.003
7	35	.007
8	34	.014
9	33	.024
10	32	.038
11	31	.056
12	30	.080
13	29	.108
14	28	.143
15	27	.185
16	26	.234
17	25	.287
18	24	.346
19	23	.406
20	22	.469
21	21	.531
	(4,4)	
10	26	.014
11	25	.029
12	24	.057
13	23	.100
14	22	.171
15	21	.243
16	20	.343
17	19	.443
18	18	.557
	(4,5)	
10	30	.008
11	29	.016
12	28	.032
13	27	.056
14	26	.095
15	25	.143
16	24	.206

T_L	$T_{1-\alpha}$	α
	(4,5) (Cont.)	
17	23	.278
18	22	.365
19	21	.452
20	20	.548
	(4,6)	
10	34	.005
11	33	.010
12	32	.019
13	31	.033
14	30	.057
15	29	.086
16	28	.129
17	27	.176
18	26	.238
19	25	.305
20	24	.381
21	23	.457
22	22	.545
	(4,7)	
10	38	.003
11	37	.006
12	36	.012
13	35	.021
14	34	.036
15	33	.055
16	32	.082
17	31	.115
18	30	.158
19	29	.206
20	28	.264
21	27	.324
22	26	.394
23	25	.464
24	24	.538
	(4,8)	
10	42	.002
11	41	.004
12	40	.008
13	39	.014
14	38	.024
15	37	.036
16	36	.055
17	35	.077
18	34	.107
19	33	.141
20	32	.184
21	31	.230
22	30	.285
23	29	.341

T_L	$T_{1-\alpha}$	α
	(4,8) (Cont.)	
24	28	.404
25	27	.467
26	26	.533
	(4,9)	
10	46	.001
11	45	.003
12	44	.006
13	43	.010
14	42	.017
15	41	.025
16	40	.038
17	39	.053
18	38	.074
19	37	.099
20	36	.130
21	35	.165
22	34	.207
23	33	.252
24	32	.302
25	31	.355
26	30	.413
27	29	.470
28	28	.530
	(4,10)	
10	50	.001
11	49	.002
12	48	.004
13	47	.007
14	46	.012
15	45	.018
16	44	.026
17	43	.038
18	42	.053
19	41	.071
20	40	.094
21	39	.120
22	38	.152
23	37	.187
24	36	.227
25	35	.270
26	34	.318
27	33	.367
28	32	.420
29	31	.473
30	30	.527
	(5,5)	
15	40	.004
16	39	.008
17	38	.016

T_L	$T_{1-\alpha}$	α
	(5,5) (Cont.)	
18	37	.028
19	36	.048
20	35	.075
21	34	.111
22	33	.155
23	32	.210
24	31	.274
25	30	.345
26	29	.421
27	28	.500
	(5,6)	
15	45	.002
16	44	.004
17	43	.009
18	42	.015
19	41	.026
20	40	.041
21	39	.063
22	38	.089
23	37	.123
24	36	.165
25	35	.214
26	34	.268
27	33	.331
28	32	.396
29	31	.465
30	30	.535
	(5,7)	
15	50	.001
16	49	.003
17	48	.005
18	47	.009
19	46	.015
20	45	.024
21	44	.037
22	43	.053
23	42	.074
24	41	.101
25	40	.131
26	39	.172
27	38	.216
28	37	.265
29	36	.319
30	35	.378
31	34	.438
32	33	.500
	(5,8)	
15	55	.001
16	54	.002

T_L	$T_{1-\alpha}$	α
	(5,8) (Cont.)	
17	53	.003
18	52	.005
19	51	.009
20	50	.015
21	49	.023
22	48	.033
23	47	.047
24	46	.064
25	45	.085
26	44	.111
27	43	.142
28	42	.177
29	41	.217
30	40	.262
31	39	.311
32	38	.362
33	37	.416
34	36	.472
35	35	.528
	(5,9)	
15	60	.000
16	59	.001
17	58	.002
18	57	.003
19	56	.006
20	55	.009
21	54	.014
22	53	.021
23	52	.030
24	51	.041
25	50	.056
26	49	.073
27	48	.095
28	47	.120
29	46	.149
30	45	.182
31	44	.219
32	43	.259
33	42	.303
34	41	.350
35	40	.399
36	39	.449
37	38	.500
	(5,10)	
15	65	.000
16	64	.001
17	63	.001
18	62	.002
19	61	.004

T_L	$T_{1-\alpha}$	α
	(5,10) (Cont.)	
20	60	.006
21	59	.010
22	58	.014
23	57	.020
24	56	.028
25	55	.038
26	54	.050
27	53	.065
28	52	.082
29	51	.103
30	50	.127
31	49	.155
32	48	.185
33	47	.220
34	46	.257
35	45	.297
36	44	.339
37	43	.384
38	42	.430
39	41	.477
40	40	.523
	(6,6)	
21	57	.001
22	56	.002
23	55	.004
24	54	.008
25	53	.013
26	52	.021
27	51	.032
28	50	.047
29	49	.066
30	48	.090
31	47	.120
32	46	.155
33	45	.197
34	44	.242
35	43	.294
36	42	.350
37	41	.409
38	40	.469
39	39	.531
	(6,7)	
21	63	.001
22	62	.001
23	61	.002
24	60	.003
25	59	.005
26	58	.011
27	57	.017

T_L	$T_{1-\alpha}$	α
	(6,7) (Cont.)	
28	56	.026
29	55	.037
30	54	.051
31	53	.069
32	52	.090
33	51	.117
34	50	.147
35	49	.183
36	48	.223
37	47	.267
38	46	.314
39	45	.365
40	44	.418
41	43	.473
42	42	.527
	(6,8)	
21	69	.000
22	68	.001
23	67	.001
24	66	.002
25	65	.004
26	64	.006
27	63	.010
28	62	.015
29	61	.021
30	60	.030
31	59	.041
32	58	.054
33	57	.071
34	56	.091
35	55	.114
36	54	.141
37	53	.172
38	52	.207
39	51	.245
40	50	.286
41	49	.331
42	48	.377
43	47	.426
44	46	.475
45	45	.525
	(6,9)	
21	75	.000
22	74	.000
23	73	.001
24	72	.001
25	71	.002
26	70	.001

T_L	$T_{1-\alpha}$	α
	(6,9) (Cont.)	
28	68	.009
29	67	.013
30	66	.018
31	65	.025
32	64	.033
33	63	.044
34	62	.057
35	61	.072
36	60	.091
37	59	.112
38	58	.136
39	57	.164
40	56	.194
41	55	.228
42	54	.264
43	53	.303
44	52	.344
45	51	.388
46	50	.432
47	49	.477
48	48	.523
	(6,10)	
21	81	.000
22	80	.000
23	79	.000
24	78	.001
25	77	.001
26	76	.002
27	75	.001
28	74	.003
29	73	.005
30	72	.011
31	71	.016
32	70	.023
33	69	.028
34	68	.036
35	67	.047
36	66	.059
37	65	.074
38	64	.090
39	63	.110
40	62	.132
41	61	.157
42	60	.184
43	59	.214
44	58	.246
45	57	.281
46	56	.318
47	55	.356

Source: Dixon and Massey, 1969

Example Problem for the Mann-Whitney U-Test

BOX 13.6 Mann-Whitney *U* Test and Wilcoxon Two-Sample Test for Two Samples, *Ranked Observations, Not Paired*

Two unrelated random samples of the shower discharge from each of 11 men are measured to the nearest 5 cc and ranked in the order listed.

(1)	(2)	(3)	(4)
Sample A		Sample B	
Y	Rank (R)	Y	Rank (R)
100	2	100	1
100	2	105	3
115	9	105	4.5
114	10	105	4.5
116	11.5	108	6
118	13.5	111	8
118	13.5	116	11.5
119	15	120	16
121	17.5	121	17.5
123	19.5	123	19.5
125	21		$91.5 = \sum R$
126	22.5		
126	22.5		
128	25		
128	25		
128	25		
	$259.5 = \sum R$		

Source: Data by D. A. Crossley.

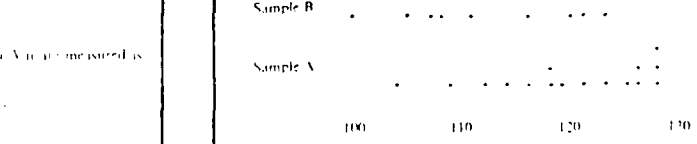
Denote the sample size of larger sample as n_1 and that of the smaller sample as n_2. In the case here, $n_1 = 16$, $n_2 = 10$. If the two samples are of equal size, it does not matter which is designated as 1.

There are two equivalent procedures for carrying out a test of equality of "location" of two samples.

The Mann-Whitney U test

1. List the observations from the smallest to the largest in such a way that the two samples may be easily compared. A convenient method is to make a graph as shown below.

BOX 13.6 (continued)



2. For each observation in one sample (it is convenient to use the smaller sample) count the number of observations in the other sample that are lower in value (to the left). Count $\frac{1}{2}$ for each tied observation. For example, there are zero observations in Sample A less than the first observation in Sample B. 1 observation less than the second, third, fourth, and fifth observations in Sample B. 2 observations in A less than the sixth in B. 4 observations in A less than the seventh in B, but one is equal (tied) with it, so we count 4$\frac{1}{2}$. Continuing in a similar manner, we obtain counts of 8, 8$\frac{1}{2}$, and 9$\frac{1}{2}$. The sum of these counts is $C = 36\frac{1}{2}$. The Mann-Whitney statistic U_s is the greater of the two quantities C and $[n_1 n_2 - C]$; in this case $36\frac{1}{2}$ and $(16 \cdot 10 - 36\frac{1}{2} = 123\frac{1}{2})$.

The Wilcoxon two-sample test

1. Rank all of the observations together from low to high, as shown in columns (2) and (4) above. Give average ranks in case of ties.

2. Sum the ranks of the smaller sample (sample size n_2).

3. Compute the Wilcoxon statistic as

$$C = n_1 n_2 + \frac{n_2(n_2+1)}{2} - \sum R = 16(10) + \frac{10(10+1)}{2} - 91.5$$

$$= 160 + 55 - 91.5 = 123.5$$

where n_1 is the size of the larger sample and n_2 is the size of the smaller. This statistic must be computed with $n_1 n_2 - C$ and the greater of the two quantities chosen as a test statistic U_s. In this case, $160 - 123.5 = 36.5$, so we use 123.5, which is identical to the value obtained in the Mann-Whitney test.

Testing the significance of U_s

No tied variates in samples (or variates tied within one or both groups only). When $n_1 \leq 20$, compare U_s with critical value for $U_{\alpha(2),n_1,n_2}$ in Table 29. The null hypothesis is rejected if the observed value is too large.

In cases where $n_1 > 20$, calculate the following quantity

$$t_s = \frac{\left(U_s - \frac{n_1 n_2}{2}\right)}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

BOX 13.6 (continued)

which is approximately normally distributed. The denominator $\sqrt{\quad}$ is the standard error of U_s. Look up the significance of t_s in Table 12 in the row of degrees of freedom $= \infty$ for a two-tailed test or two-tailed test as required by the hypothesis.

Tied variates (no variates across both samples). The test is not exact when $n_1 > 20$, but the critical values in Table 29 are conservative. That is, the actual probability value will be less than the tabled one. Our example is a case in point. Ranks of 11.5, 13.5, 17.5, 19.5, and 22.5 are tied *across* samples (ranks for variates 9.0, 21, 25, and 25 are tied *within* samples). We consult Table 29 and find $U_{0.05(2),16,10} = 113$ and $U_{0.01(2),16,10} = 124$. Hence the two samples are significantly different at least at $0.05 > P > 0.02$ (we do not cite the probabilities because this is a two-tailed test).

For sample sizes $n_1 > 20$, and when an approximation to the correct probability value is desired, evaluate

$$t_s = \frac{\left(U_s - \frac{n_1 n_2}{2}\right)}{\sqrt{\left(\frac{n_1 n_2}{n_1 + n_2 - 1}\right)\left(\frac{(n_1 + n_2)^3 - (n_1 + n_2)}{12} - \sum T\right)}}$$

where $\sum T$ has the same meaning as in Box 13.5. Compare t_s with $t_{\alpha(2),\infty}$. For our example we compute

$$t_s = \frac{\left(123.5 - \frac{16 \cdot 10}{2}\right)}{\sqrt{\left(\frac{16 \cdot 10}{16 + 10}\right)\left(\frac{(16+10)^3 - (16+10)}{12} - \frac{6 + 6 + 6 + 6 + 6 + 6}{12}\right)}}$$

$$= \frac{43.5}{\sqrt{358.7692}} = 2.297$$

The two samples are significantly different at $0.05 > P > 0.02$. The corresponding value of t_s without the correction for ties is 2.293, so in this case the conclusions are virtually the same.

Sources: Sokal and Rohlf, 1981

TABLE CC. Critical values of U, the Mann-Whitney statistic

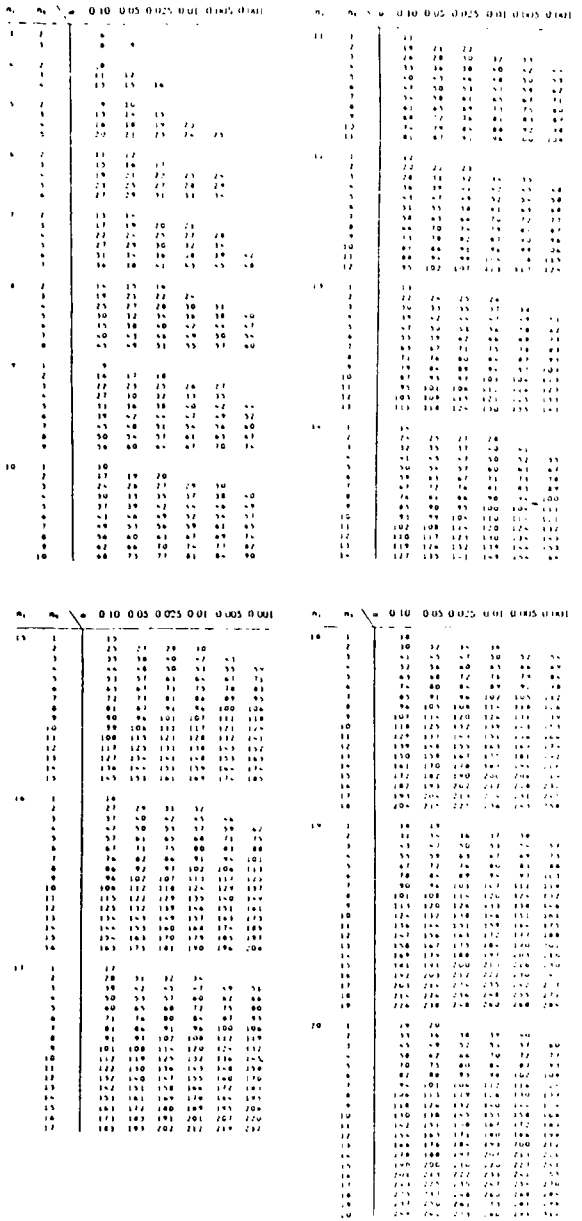
The quantity U is known as Wilcoxon's two-sample statistic or as the Mann-Whitney statistic. Critical values are tabulated for two samples of sizes n_1 and n_2, where $n_1 \geq n_2$, up to $n_1 = n_2 = 20$. As here presented (and discussed in Section 13.10) the upper bounds of the critical values are furnished so that the sample statistic U_s has to be greater than a given critical value. Some other tables of these critical values give the lower bounds. The probabilities at the heads of the columns are based on a one-tailed test and represent the proportion of the area of the distribution of U in one tail beyond the critical value. The following one-tailed probabilities are furnished: 0.10, 0.05, 0.025, 0.01, 0.005, and 0.001. For a two-tailed test use the same critical values but double the probability at the heads of the columns.

We find the critical value of U ($P = 0.025$, one-tailed) for two samples $n_1 = 14$, $n_2 = 12$ to equal 123. Any value of $U_s > 123$ will be significant at $P < 0.025$. When $n_2 > 20$, the significance of U_s can be tested by a formula given near the bottom of Box 13.6.

This table is useful for significance testing in the Mann-Whitney U-test and the Wilcoxon two-sample test (see Section 13.10 and Box 13.6), both being nonparametric tests of differences between two samples.

This table was extracted from a more extensive one (table 11.4) in D. B. Owen, *Handbook of Statistical Tables*, (Addison-Wesley Publishing Co., Reading, Mass., 1962) with permission of the publishers.

Source: Sokal and Rohlf, 1981



Critical values of the chi-square distribution

ν \ α	0.995	0.975	0.9	0.5	0.1	0.05	0.025	0.01	0.005	ν
1	[illegible]	[illegible]	0.016	0.455	2.706	3.841	5.024	6.635	7.879	1
2	0.010	0.051	0.211	1.386	4.605	5.991	7.378	9.210	10.597	2
3	0.072	0.216	0.584	2.366	6.251	7.815	9.348	11.345	12.838	3
4	0.207	0.484	1.064	3.357	7.779	9.488	11.143	13.277	14.860	4
5	0.412	0.831	1.610	4.351	9.236	11.070	12.832	15.086	16.750	5
6	0.676	1.237	2.204	5.348	10.645	12.592	14.449	16.812	18.548	6
7	0.989	1.690	2.833	6.346	12.017	14.067	16.013	18.475	20.278	7
8	1.344	2.180	3.490	7.344	13.362	15.507	17.535	20.090	21.955	8
9	1.735	2.700	4.168	8.343	14.684	16.919	19.023	21.666	23.589	9
10	2.156	3.247	4.865	9.342	15.987	18.307	20.483	23.209	25.188	10
11	2.603	3.816	5.578	10.341	17.275	19.675	21.920	24.725	26.757	11
12	3.074	4.404	6.304	11.340	18.549	21.026	23.337	26.217	28.300	12
13	3.565	5.009	7.042	12.340	19.812	22.362	24.736	27.688	29.819	13
14	4.075	5.629	7.790	13.339	21.064	23.685	26.119	29.141	31.319	14
15	4.601	6.262	8.547	14.339	22.307	24.996	27.488	30.578	32.801	15
16	5.142	6.908	9.312	15.338	23.542	26.296	28.845	32.000	34.267	16
17	5.697	7.564	10.085	16.338	24.769	27.587	30.191	33.409	35.718	17
18	6.265	8.231	10.865	17.338	25.989	28.869	31.526	34.805	37.156	18
19	6.844	8.907	11.651	18.338	27.204	30.144	32.852	36.191	38.582	19
20	7.434	9.591	12.443	19.337	28.412	31.410	34.170	37.566	39.997	20
21	8.034	10.283	13.240	20.337	29.615	32.670	35.479	38.932	41.401	21
22	8.643	10.982	14.042	21.337	30.813	33.924	36.781	40.289	42.796	22
23	9.260	11.688	14.848	22.337	32.007	35.172	38.076	41.638	44.181	23
24	9.886	12.401	15.659	23.337	33.196	36.415	39.364	42.980	45.558	24
25	10.520	13.120	16.473	24.337	34.382	37.652	40.646	44.314	46.928	25
26	11.160	13.844	17.292	25.336	35.563	38.885	41.923	45.642	48.290	26
27	11.808	14.573	18.114	26.336	36.741	40.113	43.194	46.963	49.645	27
28	12.461	15.308	18.939	27.336	37.916	41.337	44.461	48.278	50.993	28
29	13.121	16.047	19.768	28.336	39.088	42.557	45.722	49.588	52.336	29
30	13.787	16.791	20.599	29.336	40.256	43.773	46.979	50.892	53.672	30
31	14.458	17.539	21.434	30.336	41.422	44.985	48.232	52.192	55.003	31
32	15.135	18.291	22.271	31.336	42.585	46.194	49.481	53.486	56.329	32
33	15.816	19.047	23.110	32.336	43.745	47.400	50.725	54.776	57.649	33
34	16.501	19.806	23.952	33.336	44.903	48.602	51.966	56.061	58.964	34
35	17.192	20.570	24.797	34.336	46.059	49.802	53.203	57.342	60.275	35
36	17.887	21.336	25.643	35.336	47.212	50.998	54.437	58.619	61.582	36
37	18.586	22.106	26.492	36.335	48.363	52.192	55.668	59.893	62.884	37
38	19.289	22.878	27.343	37.335	49.513	53.384	56.896	61.162	64.182	38
39	19.996	23.654	28.196	38.335	50.660	54.572	58.120	62.428	65.476	39
40	20.707	24.433	29.051	39.335	51.805	55.758	59.342	63.691	66.766	40
41	21.421	25.215	29.907	40.335	52.949	56.942	60.561	64.950	68.053	41
42	22.138	25.999	30.765	41.335	54.090	58.124	61.777	66.206	69.336	42
43	22.860	26.786	31.625	42.335	55.230	59.304	62.990	67.460	70.616	43
44	23.584	27.575	32.487	43.335	56.369	60.481	64.202	68.710	71.893	44
45	24.311	28.366	33.350	44.335	57.505	61.656	65.410	69.957	73.166	45
46	25.042	29.160	34.215	45.335	58.641	62.830	66.617	71.202	74.437	46
47	25.775	29.956	35.081	46.335	59.774	64.001	67.821	72.443	75.704	47
48	26.511	30.755	35.949	47.335	60.907	65.171	69.023	73.683	76.969	48
49	27.250	31.555	36.818	48.335	62.038	66.339	70.222	74.920	78.231	49
50	27.991	32.357	37.689	49.335	63.167	67.505	71.420	76.154	79.490	50

Critical values of the chi-square distribution

ν \ α	0.995	0.975	0.9	0.5	0.1	0.05	0.025	0.01	0.005	ν
51	28.735	33.162	38.560	50.335	64.295	68.669	72.616	77.386	80.747	51
52	29.481	33.968	39.433	51.335	65.422	69.832	73.810	78.616	[illegible]	52
53	30.230	34.776	40.308	52.335	66.548	70.993	75.002	79.843	[illegible]	53
54	30.981	35.586	41.183	53.335	67.673	72.153	76.192	81.069	84.502	54
55	31.735	36.398	42.060	54.335	68.796	73.311	77.380	82.292	85.749	55
56	32.491	37.212	42.937	55.335	69.919	74.468	78.567	83.513	86.994	56
57	33.249	38.027	43.816	56.335	71.040	75.624	79.752	84.733	88.236	57
58	34.009	38.844	44.696	57.335	72.160	76.778	80.936	85.953	89.477	58
59	34.771	39.662	45.577	58.335	73.279	77.931	82.117	87.166	90.715	59
60	35.535	40.482	46.459	59.335	74.397	79.082	83.298	88.379	91.952	60
61	36.301	41.303	47.342	60.335	75.514	80.232	84.476	89.591	93.186	61
62	37.069	42.126	48.226	61.335	76.630	81.381	85.654	90.802	94.419	62
63	37.838	42.950	49.111	62.335	77.745	82.529	86.830	92.010	95.649	63
64	38.610	43.776	49.996	63.335	78.860	83.675	88.004	93.217	96.878	64
65	39.383	44.603	50.883	64.335	79.973	84.821	89.177	94.422	98.105	65
66	40.158	45.431	51.770	65.335	81.085	85.965	90.349	95.626	99.331	66
67	40.935	46.261	52.659	66.335	82.197	87.108	91.519	96.828	100.555	67
68	41.714	47.092	53.548	67.336	83.308	88.250	92.689	98.028	101.78	68
69	42.496	47.924	54.438	68.334	84.418	89.391	93.856	99.228	103.00	69
70	43.275	48.758	55.329	69.334	85.527	90.531	95.023	100.43	104.21	70
71	44.058	49.592	56.221	70.334	86.635	91.670	96.189	101.62	105.43	71
72	44.843	50.428	57.113	71.334	87.743	92.808	97.353	102.82	106.65	72
73	45.629	51.265	58.006	72.334	88.850	93.945	98.516	104.01	107.86	73
74	46.417	52.103	58.900	73.334	89.956	95.081	99.678	105.20	109.07	74
75	47.206	52.942	59.795	74.334	91.061	96.217	100.84	106.39	110.29	75
76	47.997	53.782	60.690	75.334	92.166	97.351	102.00	107.58	111.50	76
77	48.788	54.623	61.586	76.334	93.270	98.484	103.16	108.77	112.70	77
78	49.582	55.466	62.483	77.334	94.374	99.617	104.32	109.96	113.91	78
79	50.376	56.309	63.380	78.334	95.476	100.75	105.47	111.14	115.12	79
80	51.172	57.153	64.278	79.334	96.578	101.88	106.63	112.33	116.32	80
81	51.969	57.998	65.176	80.334	97.680	103.01	107.78	113.51	117.52	81
82	52.767	58.845	66.076	81.334	98.780	104.14	108.94	114.69	118.73	82
83	53.567	59.692	66.976	82.334	99.880	105.27	110.09	115.88	119.93	83
84	54.368	60.540	67.876	83.334	100.98	106.39	111.24	117.06	121.13	84
85	55.170	61.389	68.777	84.334	102.08	107.52	112.39	118.24	122.32	85
86	55.973	62.239	69.679	85.334	103.18	108.65	113.54	119.41	123.52	86
87	56.777	63.089	70.581	86.334	104.28	109.77	114.69	120.59	124.72	87
88	57.582	63.941	71.484	87.334	105.37	110.90	115.84	121.77	125.91	88
89	58.389	64.793	72.387	88.334	106.47	112.02	116.99	122.94	127.11	89
90	59.196	65.647	73.291	89.334	107.56	113.15	118.14	[illegible]	128.30	90
91	60.005	66.501	74.196	90.334	108.66	114.27	119.28	125.29	129.49	91
92	60.815	67.356	75.101	91.334	109.76	115.39	120.43	126.46	130.68	92
93	61.625	68.211	76.006	92.334	110.85	116.51	121.57	127.63	131.87	93
94	62.437	69.068	76.912	93.334	111.94	117.63	122.72	128.80	133.06	94
95	63.250	69.925	77.818	94.334	113.04	118.75	123.86	129.97	134.25	95
96	64.063	70.783	78.725	95.334	114.13	119.87	125.00	131.14	135.44	96
97	64.878	71.642	79.633	96.334	115.22	120.99	126.14	132.31	136.62	97
98	65.694	72.501	80.541	97.334	116.32	122.11	127.28	133.48	137.80	98
99	66.510	73.361	81.449	98.334	117.41	123.23	128.42	134.64	138.99	99
100	67.328	74.222	82.358	99.334	118.50	124.34	129.56	135.81	140.17	100

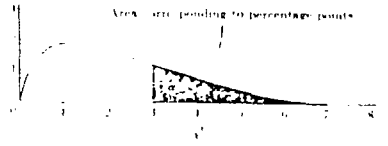
Critical values of the chi-square distribution

Table E-4 Critical values of the chi-square distribution for degrees of freedom $\nu = 1$ to 100 *in increments of 1*. The percentage points given for $\alpha = 0.995, 0.975, 0.9, 0.5, 0.1, 0.05, 0.025, 0.01$, and 0.005 represent the area to the right of the critical value of χ^2 in one tail of the distribution as shown in the accompanying figure. The critical values of χ^2 are given to three significant decimal places except in cases when $\chi^2 \geq 100$ when they are given to two significant decimal places.

To find the critical value of χ^2 for a given number of degrees of freedom, look down in the left argument column of the table and read off the desired value of ν in that row. For example, for eight degrees of freedom $\chi^2_{0.995} = 1.344$ and $\chi^2_{0.005} = 21.955$. The last value indicates that 1% of the area of the chi-square distribution for eight degrees of freedom is to the right of the value of $\chi^2 = 21.955$. For values of $\nu > 100$, compute approximate critical value of χ^2 by the formula as follows: $\chi^2_{\alpha,\nu} = \frac{1}{2}(z_{\alpha,\nu} + \sqrt{2\nu - 1})^2$, where $z_{\alpha,\nu}$ can be looked up in Table Q. Thus $\chi^2_{0.005,60}$ is computed as $\frac{1}{2}(z_{0.005,60} + \sqrt{2 \times 200 - 1})^2 = \frac{1}{2}(2.807 + \sqrt{2 \times 200 - 1})^2 = \frac{1}{2}(17.10162)^2 = 146.254$.

There are numerous applications of the chi-square distribution in statistics. The distribution is described in Section 7.6. It is used to set confidence limits to sample variances (Section 7.7), to test the homogeneity of variances (Section 13.4) and of correlation coefficients (Section 15.4), and for tests of goodness of fit (Chapter 16).

Values of chi-square from 1 to 30 degrees of freedom have been taken from a more extensive table by C. M. Thompson (*Biometrika* 32:188–189, 1941) with permission of the publisher. Values between 31 and 100 degrees of freedom were approximated using the Cornish-Fisher asymptotic expansion following the account of M. Zelen and N. C. Severo, section 26.2.49 of M. Abramowitz and I. A. Stegun (eds.), *Handbook of Mathematical Functions* (U.S. National Bureau of Standards, 1964). The values of the Hermite polynomials were computed instead of using the tables furnished in the source above.



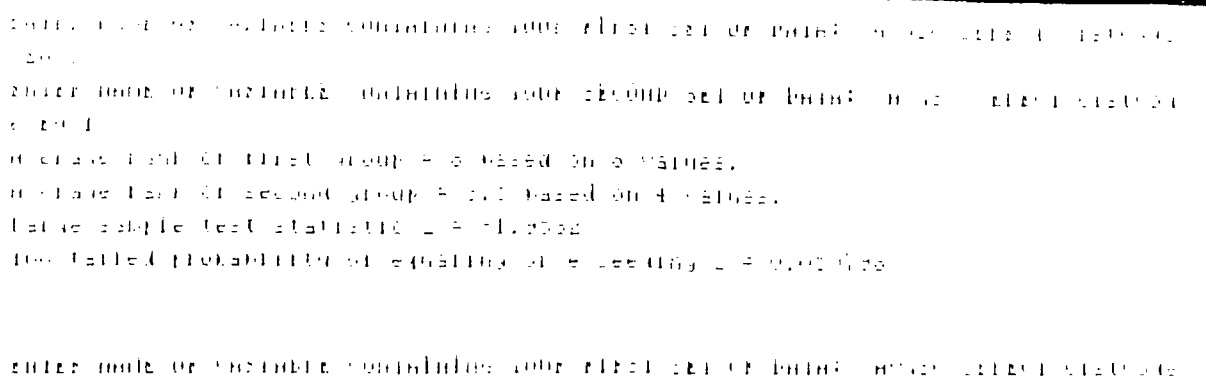
Source: Pearson and Hartley, 1954, 1966, 1972; Merrington, 1941; Fisher and Yates, 1963; Harter and Owen, 1970; Owen, 1962; Pachares, 1961; Resnikoff and Lieberman, 1957; Romig, 1953; Thompson, 1941; Wagner and Tornheim, 1955; Weast and Hodgman, 1963; Zelen and Severo, 1964; Zelen and Romig, 1951; Zelen and Severo, 1960; Zelen and Severo, 1964; Zelen and Severo, 1965; Zelen and Severo, 1968; Zelen and Severo, 1972; Zelen and Severo, 1981

ATTACHMENT E

Section E-2: STRATIGRAPHIC^{R} Results for Kruskal-Wallis Tests for TOC and pH (See Section 3, Figure 3-4, for SC Results)

ATTACHMENT E

Section E-3: STRAGRAPHICS[R] Results for Mann-Whitney-Wilcoxon Tests for SC Data



```
[illegible] CONTAINING YOUR FIRST SET OF DATA: [illegible]
[illegible]
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: [illegible]
[illegible]
Average rank of first group = 8 based on 8 values.
Average rank of second group = [illegible] based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = [illegible]


ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: [illegible]
[illegible]
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: [illegible]
[illegible]
Average rank of first group = 6.5 based on 8 values.
Average rank of second group = 6.5 based on 4 values.
Large sample test statistic Z = 0
Two-tailed probability of equaling or exceeding Z = 1


ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: [illegible]
[illegible]
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: [illegible]
[illegible]
Average rank of first group = 4.5 based on 8 values.
Average rank of second group = 10.5 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = [illegible]


ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: [illegible]
[illegible]
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: [illegible]
[illegible]
Average rank of first group = [illegible] based on 8 values.
Average rank of second group = 6 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = [illegible]
Press ENTER to continue.
```

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FIGURE E-10a
RESULTS OF STATGRAPHICS®
MANN-WHITNEY-WILCOXON TESTS
FOR SC DATA

```
ENTER NAME OF RESPONSE (PI-BLE): pH
ENTER NAME OF CLASSIFICATION (PI-BLE): Localone
Average ranks by level of Localone
[illegible]

Test statistic = [illegible]
Significance level = [illegible]
Press ENTER to continue.
```

```
ENTER NAME OF RESPONSE (PI-BLE): pH
ENTER NAME OF CLASSIFICATION (PI-BLE): Timeline
Average ranks by level of Timeline
[illegible]

Test statistic = [illegible]
Significance level = [illegible]
Press ENTER to continue.
```

NOTE: If the "Significance Level" is <0.05, a statistically significant difference is indicated. This data set includes both replicated and unreplicated background data for unclustered pH. In this example, only date of sample (Timeline) is significant.

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FIGURE E-9
RESULTS OF KRUSKAL-WALLIS TEST
FOR pH-STATGRAPHICS® PROCEDURE

BAYOU SORREL STATISTICS DEMONSTRATION

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```
ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 5
Average rank of first group = 6.25 based on 8 values.
Average rank of second group = 7 based on 4 values.
Large sample test statistic Z = 0.25416
Two-tailed probability of equaling or exceeding Z = 0.7989

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 6
Average rank of first group = 4.5 based on 8 values.
Average rank of second group = 10.5 based on 4 values.
Large sample test statistic Z = 2.6325
Two-tailed probability of equaling or exceeding Z = 8.4749E-3

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 7
Average rank of first group = 7.125 based on 8 values.
Average rank of second group = 5.25 based on 4 values.
Large sample test statistic Z = -0.16429
Two-tailed probability of equaling or exceeding Z = 0.44469

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 8
Average rank of first group = 6.25 based on 8 values.
Average rank of second group = 7 based on 4 values.
Large sample test statistic Z = 0.25416
Two-tailed probability of equaling or exceeding Z = 0.7989
```

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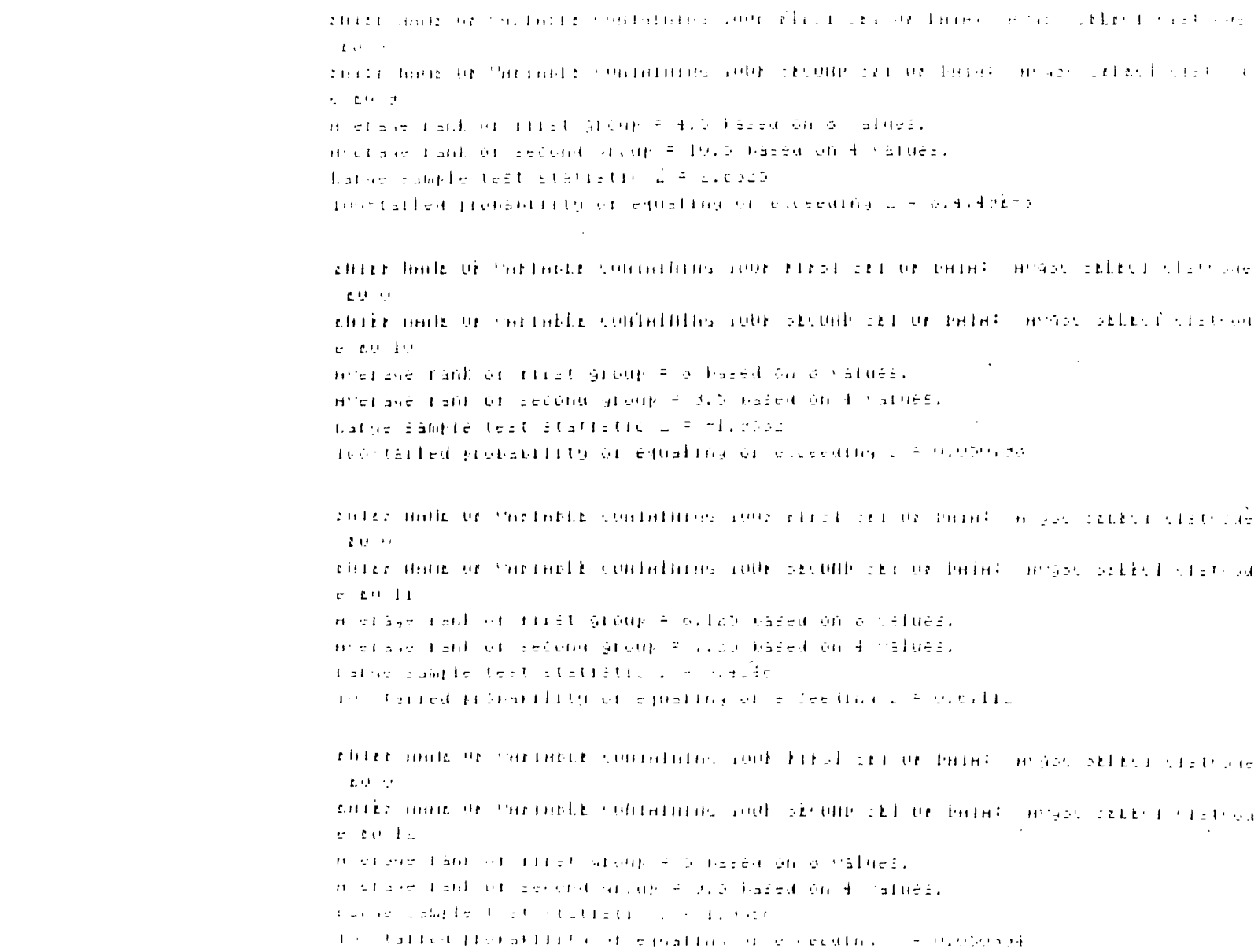
FIGURE E-10b
RESULTS OF STATGRAPHICS®
MANN-WHITNEY-WILCOXON TESTS
FOR SC DATA



```
ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 9
Average rank of first group = 4.5 based on 8 values.
Average rank of second group = 10.5 based on 4 values.
Large sample test statistic Z = 2.6325
Two-tailed probability of equaling or exceeding Z = 0.4[illegible]

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 10
Average rank of first group = 8 based on 8 values.
Average rank of second group = 3.5 based on 4 values.
Large sample test statistic Z = -1.[illegible]
Two-tailed probability of equaling or exceeding Z = 0.[illegible]

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 11
Average rank of first group = 6.125 based on 8 values.
Average rank of second group = [illegible] based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = 0.[illegible]

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 12
Average rank of first group = 5 based on 8 values.
Average rank of second group = 9.5 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = 0.[illegible]
```

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FIGURE E-10c
RESULTS OF STATGRAPHICS ®
MANN-WHITNEY-WILCOXON TESTS
FOR SC DATA

```
ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: AVGSC SELECT CISTCOD
E EQ 13
Average rank of first group = 7.125 based on 8 values.
Average rank of second group = 5.25 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = 0.44469

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: AVGSC SELECT CISTCOD
E EQ 14
Average rank of first group = 5.875 based on 8 values.
Average rank of second group = 7.75 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = 0.44469

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: AVGSC SELECT CISTCOD
E EQ 15
Average rank of first group = 4.5 based on 8 values.
Average rank of second group = 10.5 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = [illegible]

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA: AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA: AVGSC SELECT CISTCOD
E EQ 16
Average rank of first group = 7.625 based on 8 values.
Average rank of second group = 4.25 based on 4 values.
Large sample test statistic Z = [illegible]
Two-tailed probability of equaling or exceeding Z = [illegible]
```

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FIGURE E-10d
RESULTS OF STATGRAPHICS ®
MANN-WHITNEY-WILCOXON TESTS
FOR SC DATA

```
ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 1.
Average rank of first group = 6 based on 6 values.
Average rank of second group = 7.5 based on 4 values.
Large sample test statistic Z = 0.59445
Two-tailed probability of equaling or exceeding Z = 0.55221
Press ENTER to continue.

ENTER NAME OF VARIABLE CONTAINING YOUR FIRST SET OF DATA:  AVGSC SELECT CISTCODE
 EQ 0
ENTER NAME OF VARIABLE CONTAINING YOUR SECOND SET OF DATA:  AVGSC SELECT CISTCOD
E EQ 16
Average rank of first group = 4.75 based on 6 values.
Average rank of second group = 10 based on 4 values.
Large sample test statistic Z = 2.2929
Two-tailed probability of equaling or exceeding Z = 0.021656
Press ENTER to continue.
```

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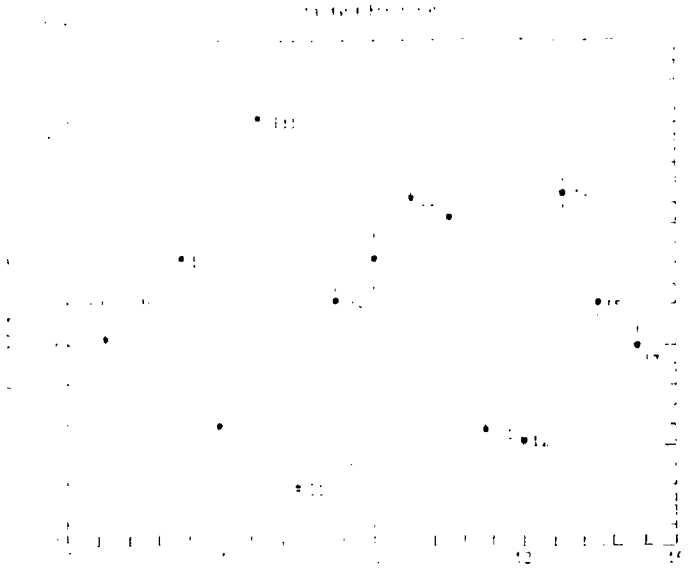
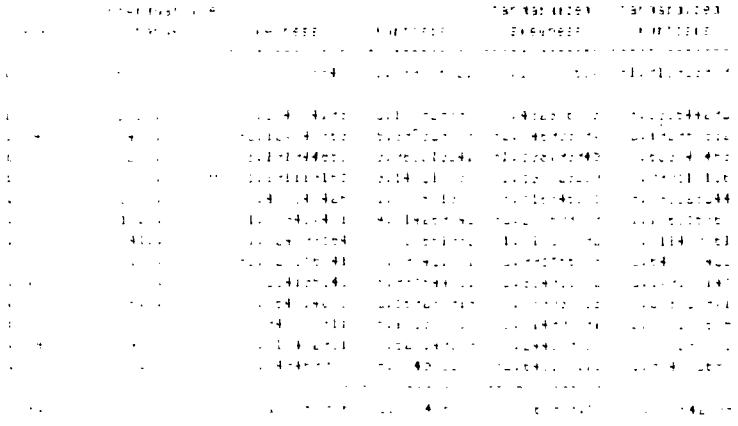
FIGURE E-10e
RESULTS OF STATGRAPHICS®
MANN-WHITNEY-WILCOXON TESTS
FOR SC DATA





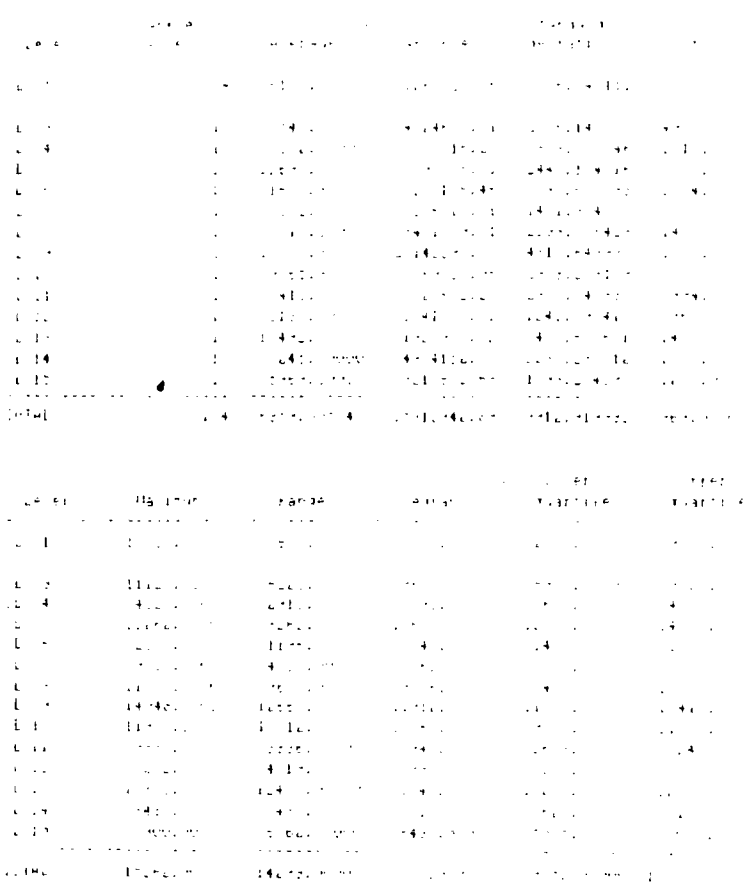


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FIGURE C-5
CODE BOOK PROCEDURE
FOR UNCLUSTERED SC DATA BASE
BAYOU CORPUS STATISTICS DEMONSTRATION

W.O. NO	20-08	DATE	7/14/87

Level	Sample size	Average	Variance	Standard deviation	Minimum
CL 1	8	6170.87500	12332125.84	3511.712665	2700.00000
CL 2	4	2450.00000	670000.00	818.535277	1700.00000
CL 3	4	7325.00000	1051250.00	1025.304813	5975.00000
CL 4	4	11693.75000	2281918.92	1510.602170	10263.00000
CL 5	4	4643.50000	1330118.2.33	3647.078603	1104.00000
CL 6	4	8041.75000	1811005.58	1345.736075	6425.00000
CL 7	4	12131.25000	2280882.25	1510.259001	10457.00000
CL 8	4	3284.75000	2038964.25	1425.119030	1402.00000
CL 9	4	7000.00000	3615833.33	1901.534468	4975.00000
CL 10	4	11553.25000	3217100.92	1103.226594	10263.00000
CL 11	4	2509.25000	1055071.58	1027.166775	1312.00000
CL 12	4	8062.50000	2721041.67	1649.558022	6300.00000
CL 13	4	11662.50000	5951875.00	2439.646491	9950.00000
CL 14	4	3499.25000	2562598.92	1600.811955	1455.00000
CL 15	4	8622.75000	2783720.92	1668.448656	7300.00000
CL 16	4	12615.50000	4188427.67	2046.564845	11000.00000
CL 17	4	2756.25000	1135989.58	1065.828121	1400.00000
CL 18	4	8487.50000	3300208.33	1816.647553	7000.00000
CL 19	4	11425.00000	4614166.67	2148.061141	9700.00000
TOTAL	80	7545.27500	15173769.64	3895.352313	1304.00000

Level	Maximum	Range	Median	Lower quartile	Upper quartile
CL 1	10100.00000	7400.00000	5883.50000	2850.00000	9550.00000
CL 2	3600.00000	1900.00000	2250.00000	1900.00000	3000.00000
CL 3	8400.00000	2425.00000	7462.50000	6587.50000	8062.50000
CL 4	13412.00000	3149.00000	11550.00000	10431.50000	12956.00000
CL 5	9830.00000	8526.00000	3720.00000	2377.00000	6910.00000
CL 6	9720.00000	3295.00000	8011.00000	7208.50000	8875.00000
CL 7	14048.00000	3591.00000	12010.00000	11028.50000	13234.00000
CL 8	4537.00000	3135.00000	3600.00000	2188.50000	4381.00000
CL 9	8975.00000	4000.00000	8625.00000	6675.00000	8925.00000
CL 10	12700.00000	2437.00000	11625.00000	10656.50000	12450.00000
CL 11	3787.00000	2475.00000	2469.00000	1781.00000	3217.50000
CL 12	9825.00000	3525.00000	8062.50000	6687.50000	9437.50000
CL 13	15125.00000	5175.00000	10787.50000	9950.00000	13375.00000
CL 14	5282.00000	3827.00000	3630.00000	2350.00000	4648.50000
CL 15	10900.00000	3600.00000	8101.50000	7460.00000	9785.50000
CL 16	15262.00000	4262.00000	12100.00000	11000.00000	14231.00000
CL 17	4000.00000	2600.00000	2812.50000	2062.50000	3450.00000
CL 18	11125.00000	4125.00000	7912.50000	7362.50000	9612.50000
CL 19	14500.00000	4800.00000	10750.00000	9975.00000	12875.00000
TOTAL	15262.00000	13950.00000	8865.00000	3693.50000	10360.00000

Level	Interquartile range	Skewness	Kurtosis	Standardized skewness	Standardized kurtosis
CL 1	6700.00000	.053851269	1.887318126	.861258328	1.184287395
CL 2	1100.00000	.741139274	2.059775748	.605137683	.383844943
CL 3	1475.00000	.412818847	1.883271288	.337864524	.455982587
CL 4	2524.50000	.151832493	1.259858158	.123978711	.716849932
CL 5	4533.00000	.795766995	2.135744857	.649741031	-.352831811
CL 6	1666.50000	.079878401	2.008859742	.064567244	-.407897302
CL 7	2205.50000	.248393602	1.831779679	.202812527	.476923949
CL 8	2192.50000	.519782917	1.784854821	.424480974	.529867404
CL 9	2450.00000	1.091091753	2.278992491	.890872686	.294349879
CL 10	1793.50000	-.142421985	1.622861773	-.116287864	.644190584
CL 11	1456.50000	.127237135	1.886781644	.103888686	-.454468674
CL 12	2750.00000	.000000000	1.272656522	.000000000	.705185822
CL 13	1425.00000	.834113863	2.019104621	.681051117	-.408446820
CL 14	2298.50000	-.258600914	1.870627835	-.211146762	.461064256
CL 15	2125.50000	.821220435	2.028699529	.670523677	.496568499
CL 16	1231.00000	.462644286	1.590884652	.377747412	.575268932
CL 17	1387.50000	.188499127	1.989568996	.153769208	.412510000
CL 18	2250.00000	.944411998	2.189217885	.762445181	.331081555
CL 19	2900.00000	.866592287	2.891875393	.707569640	.171866917
TOTAL	6646.50000	.807756996	1.895446942	.112088522	2.016628752

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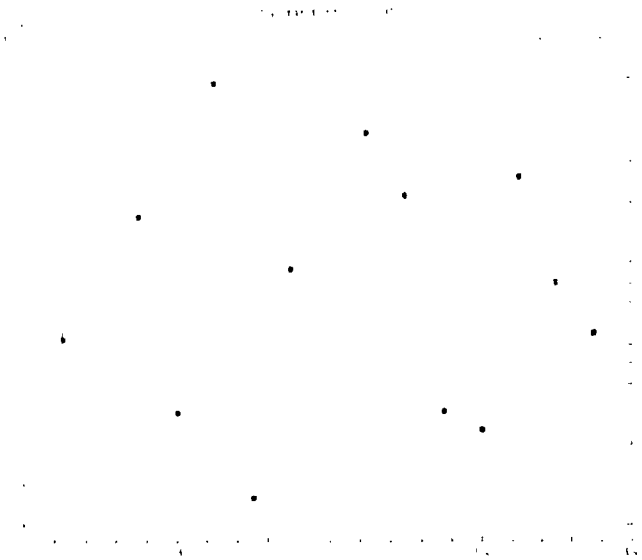
FIGURE C-6

CODE BOOK PROCEDURE

FOR DATA SPECIFIC SC CLUSTERS

BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO.	20-08	DATE	7-14-88



Level	Sample size	Average	Variance	Standard deviation	Minimum
CL 1	8	6170.87500	12332125.84	3511.712665	2700.00000
CL 2	6	9838.83333	1161114.17	1077.550076	8400.00000
CL 3	6	3936.16667	46374.17	215.3466220	3600.00000
CL 4	6	13751.16667	18346312.17	1354.685942	12420.00000
CL 5	6	1428.83333	21000.17	144.9143431	1304.00000
CL 6	6	8237.50000	517053.10	719.0640440	7200.00000
CL 7	6	12255.83333	1507693.77	1227.881821	11000.00000
CL 8	6	10403.33333	2993900.27	547.1656667	9700.00000
CL 9	6	3977.16667	838267.817	2881.436823	2400.00000
CL 10	6	3419.83333	1619466.57	1272.582636	2100.00000
CL 11	6	10977.16667	1513000.17	1230.043969	9950.00000
CL 12	6	7820.83333	286914.17	454.8781889	7075.00000
CL 13	6	6329.16667	672354.17	819.9720952	4975.00000
TOTAL	80	7545.27500	15173769.64	3895.352313	1304.00000

Level	Maximum	Range	Median	Lower quartile	Upper quartile
CL 1	10100.00000	7400.00000	5883.50000	2850.00000	9550.00000
CL 2	11125.00000	2725.00000	9772.50000	8975.00000	10988.00000
CL 3	4225.00000	625.00000	3995.00000	3787.00000	4015.00000
CL 4	15262.00000	2842.00000	13600.00000	12500.00000	15125.00000
CL 5	1700.00000	396.00000	1401.00000	1312.00000	1455.00000
CL 6	9050.00000	1850.00000	8287.50000	7725.00000	8875.00000
CL 7	14048.00000	3048.00000	11912.50000	11250.00000	13412.00000
CL 8	11050.00000	1350.00000	10350.00000	9950.00000	11000.00000
CL 9	9830.00000	7430.00000	2850.00000	2688.00000	3245.00000
CL 10	5282.00000	3182.00000	3175.00000	2250.00000	4537.00000
CL 11	13200.00000	3250.00000	10431.50000	10250.00000	11600.00000
CL 12	8375.00000	1300.00000	7877.50000	7620.00000	8100.00000
CL 13	7300.00000	2325.00000	6362.50000	5975.00000	7000.00000
TOTAL	15262.00000	13958.00000	4865.00000	3693.50000	10150.00000

Level	Interquartile range	Skewness	Kurtosis	Standardized skewness	Standardized kurtosis
CL 1	6700.00000	0.5405051269	1.808731B126	0.6125B8328	1.1842B7395
CL 2	2013.00000	0.0835131496	1.6597181324	0.0835131496	0.7814468B
CL 3	228.000000	1.577446671	2.2642489447	1.577446671	3.67875527
CL 4	2625.00000	0.0866347Z6	1.1336308B18	0.0866347Z6	0.933184591
CL 5	143.00000	1.178787141	3.1769111274	1.178787141	0.0846563Z
CL 6	1150.00000	0.2538792B4	1.6557611496	0.2538792B4	0.7118B152
CL 7	2162.00000	0.4795646638	1.6652294866	0.4795646638	0.6738508Z
CL 8	1050.00000	0.0523516661	1.5769465Z5	0.0523516661	0.711526717
CL 9	557.00000	1.749740923	4.1296755559	1.749740923	0.5648377779
CL 10	2287.00000	0.4051570Z8	1.6980668627	0.4051570Z8	0.5Z0669686
CL 11	1150.00000	1.099345056	2.7506963633	1.099345056	0.1246515Z9
CL 12	488.000000	0.5185529B8	2.3176437Z4	0.5185529B8	0.3411781Z3
CL 13	1025.00000	0.5205418177	2.3728B4Z1	0.5205418177	0.3159778Z9
TOTAL	6666.50000	0.3075695Z6	1.8954469Z2	112.3085Z2	2.0166287Z

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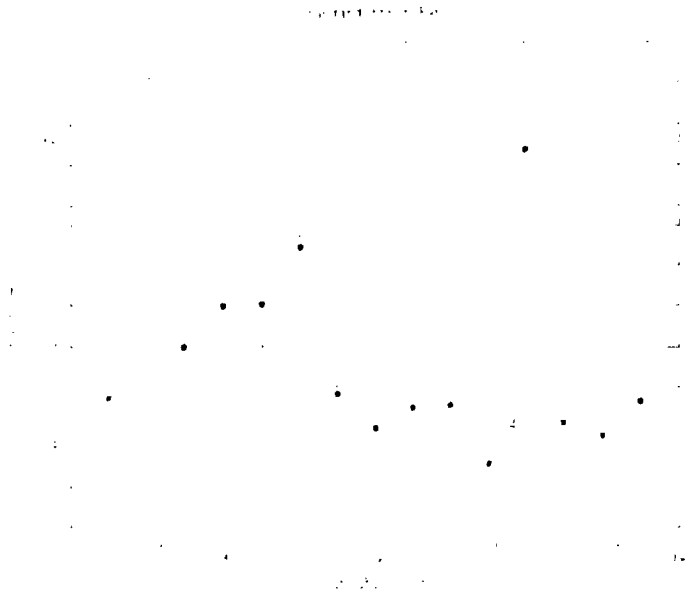
FIGURE C-7

CODE BOOK PROCEDURE

FOR WELL SPECIFIC SC CLUSTERS

BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO.	20-08	DATE	7-14-87



Level	Sample size	Average	Variance	Standard deviation	Minimum
CL 1	24	59.1545833	1154.07895	33.9717375	10.20000000
CL 2	10	79.4900000	3465.71433	58.8703179	1.00000000
CL 3	10	96.1810000	2451.49250	49.5125489	4.00000000
CL 4	10	96.6700000	16729.99344	129.3444759	13.00000000
CL 5	10	119.1400000	5010.11156	70.7821415	40.50000000
CL 6	10	60.7050000	1565.38358	39.5649287	1.00000000
CL 7	10	47.1000000	666.44444	25.8155853	18.80000000
CL 8	10	55.5100000	911.69433	30.1942765	21.30000000
CL 9	10	56.3200000	867.65956	29.4560614	21.00000000
CL 10	10	33.4800000	958.15067	30.9540089	10.20000000
CL 11	10	157.9890000	5622.27143	74.9818073	34.70000000
CL 12	10	50.0800000	722.06622	26.8712899	23.00000000
CL 13	10	44.0500000	705.16278	26.5549012	19.00000000
CL 14	10	57.9400000	805.46044	28.3806350	25.30000000
TOTAL	154	71.2094805	3565.25907	59.7097904	1.00000000

Level	Maximum	Range	Median	Lower quartile	Upper quartile
CL 1	112.0000000	101.8000000	59.0100000	29.8500000	87.4150000
CL 2	220.0000000	219.0000000	77.3000000	38.0000000	97.0000000
CL 3	167.0000000	163.0000000	92.9500000	73.0000000	122.4000000
CL 4	458.0000000	445.0000000	59.4000000	40.9000000	83.2000000
CL 5	270.0000000	229.5000000	110.3500000	57.5000000	149.0000000
CL 6	127.2000000	126.2000000	49.4500000	35.5000000	98.0000000
CL 7	89.2000000	70.4000000	43.5000000	28.0000000	61.1000000
CL 8	107.0000000	85.7000000	54.3000000	28.0000000	73.4000000
CL 9	98.6000000	77.6000000	64.1500000	25.0000000	75.0000000
CL 10	112.0000000	101.8000000	23.0000000	11.0000000	40.9000000
CL 11	289.5000000	254.8000000	179.0000000	120.0000000	186.0000000
CL 12	89.5000000	66.5000000	35.8500000	29.0000000	75.0000000
CL 13	106.0000000	87.0000000	35.3000000	31.0000000	42.0000000
CL 14	118.0000000	92.7000000	45.4000000	41.0000000	71.1000000
TOTAL	458.0000000	457.0000000	58.0650000	32.4000000	89.5000000

Level	Interquartile range	Skewness	Kurtosis	Standardized skewness	Standardized kurtosis
CL 1	57.56500000	.022964462	1.80442653	.04592892	-1.19557347
CL 2	59.00000000	1.23024557 4	4.47993242	1.58824021	.95529227
CL 3	49.40000000	-.25706719 1	2.48066902	-.33187232	-.33522671
CL 4	42.30000000	2.48627257 8	7.55537526	3.20976410	2.94048209
CL 5	91.50000000	.84814503 9	2.99456125	1.09495054	.00351070
CL 6	62.50000000	.25339597 4	1.98958351	.32713280	.65222104
CL 7	33.10000000	.51863501 2	1.94112711	.66955492	.68349951
CL 8	45.40000000	.40388540 0	1.86944056	.52141381	.72977298
CL 9	50.00000000	-.04123866 8	1.48845331	-.05323889	.97569919
CL 10	29.90000000	1.78358970 2	5.25240386	2.30260440	1.45392044
CL 11	66.00000000	.11134462 6	2.54341504	.14374529	.29472432
CL 12	46.00000000	.40608184 9	1.35939759	.52424941	1.05900430
CL 13	11.00000000	1.52185249 1	4.06611275	1.96470312	.68817282
CL 14	30.10000000	1.06910024 5	3.04223554	1.38020248	.02726293
TOTAL	57.10000000	2.67761536 9	14.77194700	13.56541009	29.81968405

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FIGURE C 9
CODE BOOK PROCEDURE
FOR TOC BY WELL LOCATION
BAYOU SORREL STATISTICS DEMONSTRATION

W.O. NO. 20 08 | DATE 7/14/83

Rank Sum Test For Several Samples: Kruskal-Wallis Test

BOX 13.5 Kruskal-Wallis Test. A Test for Differences of Location in Ranked Data Grouped by Single Classification

Effect of different sugars on growth of pea sections. Data from Box 9.1. a = 5 groups. n = number of items in group (in this example sample sizes are equal: $n_1 = n_2 = 10$).

Computations

1. Rank all observations from smallest to largest when pooled together into a single sample. In case of ties compute the average ranks. For example, the 3 variates 20 have ranks 18, 19, 20, and 21. Their average rank therefore equals $(18 + 19 + 20 + 21)/4 = 19.5$.

Average Rank	Rank	Y
	1	56
3	2	56
	3	56
	4	57
	5	57
	6	57
7	7	57
	8	57
	9	57
	10	57
	11	58
	12	58
	13	58
14	14	58
	15	58
	16	58
	17	58
	18	59
19.5	19	59
	20	59
	21	59
	22	60
23.5	23	60
	24	60
	25	60
	26	61
27.5	27	61
	28	61
	29	61
	30	62
31.5	31	62
	32	62
	33	62
	34	63
	35	64
	36	65
37.5	37	65
	38	65
	39	65
	40	66
	41	67
42.5	42	67
	43	67
	44	67
	45	68
	46	70
	47	71
48.5	48	75
	49	75
	50	76

Source: Sokal and Rohlf, 1981

BOX 13.5 (continued)

2. Replace each observation in the original data table by its rank or average rank.

Control		2% glucose added		2% fructose added		1% glucose + 1% fructose added		2% sucrose added	
Y	Rank	Y	Rank	Y	Rank	Y	Rank	Y	Rank
75	48.5	57	7	58	11	58	14	62	31.5
67	42.5	58	11	61	27.5	59	19.5	66	40
70	46	60	23.5	59	2	58	14	65	37.5
75	48.5	59	19.5	58	14	61	27.5	63	34
63	37.5	62	31.5	57	7	57	7	64	35
71	47	60	23.5	56	2	56	2	62	31.5
67	42.5	60	23.5	61	27.5	58	14	65	37.5
67	42.5	57	7	60	23.5	57	2	65	37.5
76	50	59	19.5	57	7	57	7	62	31.5
68	45	61	27.5	58	14	59	19.5	67	42.5
$\sum R_i$	450.0		196.5		138.5		131.5		358.5

3. Sum the ranks separately for each group. Enter in row $\left(\sum R\right)_i$. For example $\left(\sum R\right)_1 = 48.5 + 42.5 + \cdots + 50 + 45 = 450.0$.

4. Compute Expression (13.4). The numbers 12 and 3 are constants.

$$H = \left[\frac{12}{\left(\sum n_i\right)\left(\sum n_i + 1\right)}\sum\frac{\left(\sum R\right)_i^2}{n_i}\right] - 3\left(\sum n_i + 1\right)$$

$$= \frac{12}{50(50+1)}\left[\frac{450.0^2}{10} + \frac{196.5^2}{10} + \cdots + \frac{358.5^2}{10}\right] - 3(50+1)$$

$$= \frac{12}{50(51)}(42{,}076.0900) - 3(51) = 991.110 - 153 = 38.110$$

5. Since there were ties, this H value must be corrected by dividing it by

$$D = 1 - \frac{\sum T_i}{\left(\sum n_i - 1\right)\sum n_i\left(\sum n_i + 1\right)}$$

where T_i is a function of the t_i, the number of variates tied in the ith group of ties. (This t has no relation to Student's t.) The function is $T_i = t_i^3 - t_i$, computed most easily as $T_i = (t_i - 1)t_i(t_i + 1)$, since in most cases the tied group will range

BOX 13.5 (continued)

from $t = 2$ to $t = 10$. Ties we give a small table of T over this range. The summation of T_i is over the m different ties.

t_i	2	3	4	5	6	7	8	9	10
T_i	6	24	60	120	210	336	504	720	990

For example, for the first tied group in the table of ranks, $t_1 = 3$, since there are 3 variates of equal magnitude.

The t_i's for the present example are shown below, together with the corresponding T_i's.

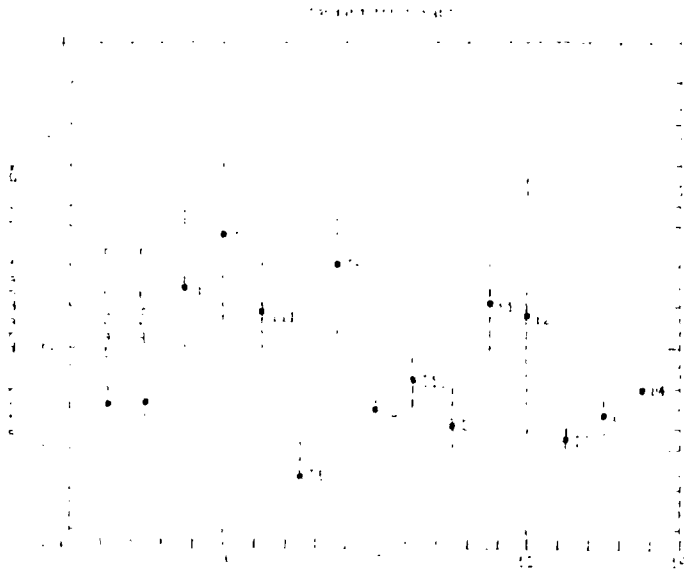
t_i	3	7	7	4	4	4	4	4	4	2
T_i	24	336	336	60	60	60	60	60	60	6

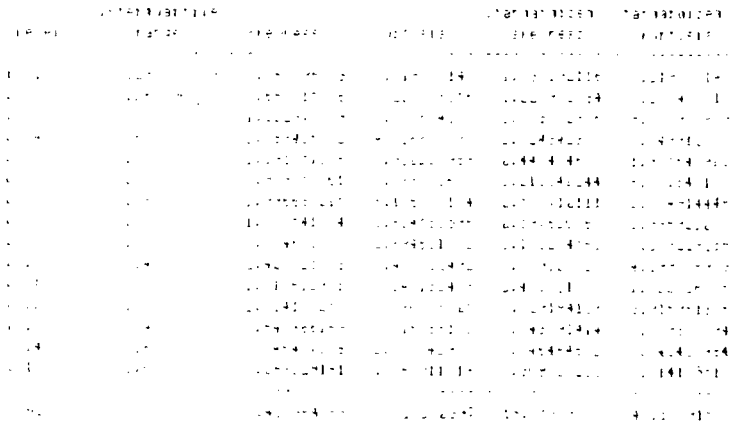
$$\sum T_i = 24 + 336 + \cdots + 6 = 1062$$

$$D = 1 - \frac{1062}{(50-1)50(50+1)} = 1 - \frac{1062}{49(50)51} = 1 - \frac{1062}{124{,}950} = 1 - 0.008500 = 0.991500$$

$$\text{Adjusted } H = \frac{H}{D} = \frac{38.110}{0.991500} = 38.437$$

If the null hypothesis (that the a groups do not differ in location) is true, H is distributed approximately as χ^2_{a-1}. Since H is much greater than $\chi^2_{0.05[5-1]} = 13.3643$, we may confidently reject the null hypothesis and conclude that different sugars affect rate of growth of pea sections differentially. Box 13.6 gives a method for unplanned testing of differences among treatments.





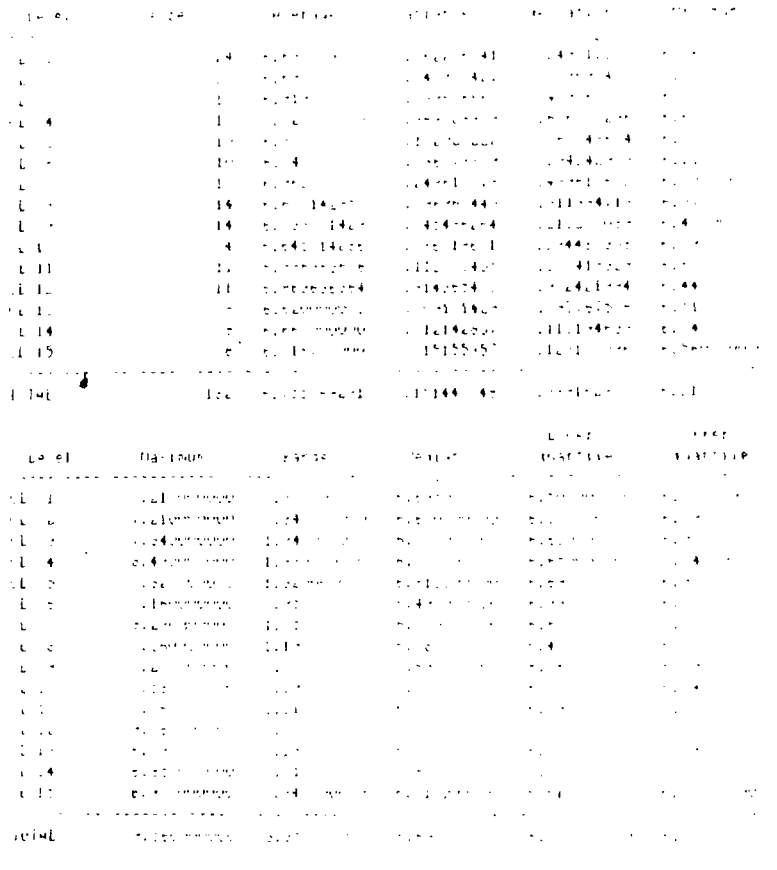


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FIGURE C-10
CODE BOOK PROCEDURE
FOR UNCLUSTERED pH DATA
BAYOU SORREL STATISTICS DEMONSTRATION

WO NO	20-08	DATE	7/14/87

Parameter	Estimate	Error	Value	Prob.
Intercept	[illegible]	[illegible]	[illegible]	[illegible]
Slope	[illegible]	[illegible]	[illegible]	[illegible]

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-ratio	
Model	[illegible]	1	[illegible]	[illegible]	
Error	[illegible]	6	[illegible]		
Total (Corr.)	[illegible]	7			

Correlation Coefficient = [illegible]
Stnd. Error of Est. = [illegible]

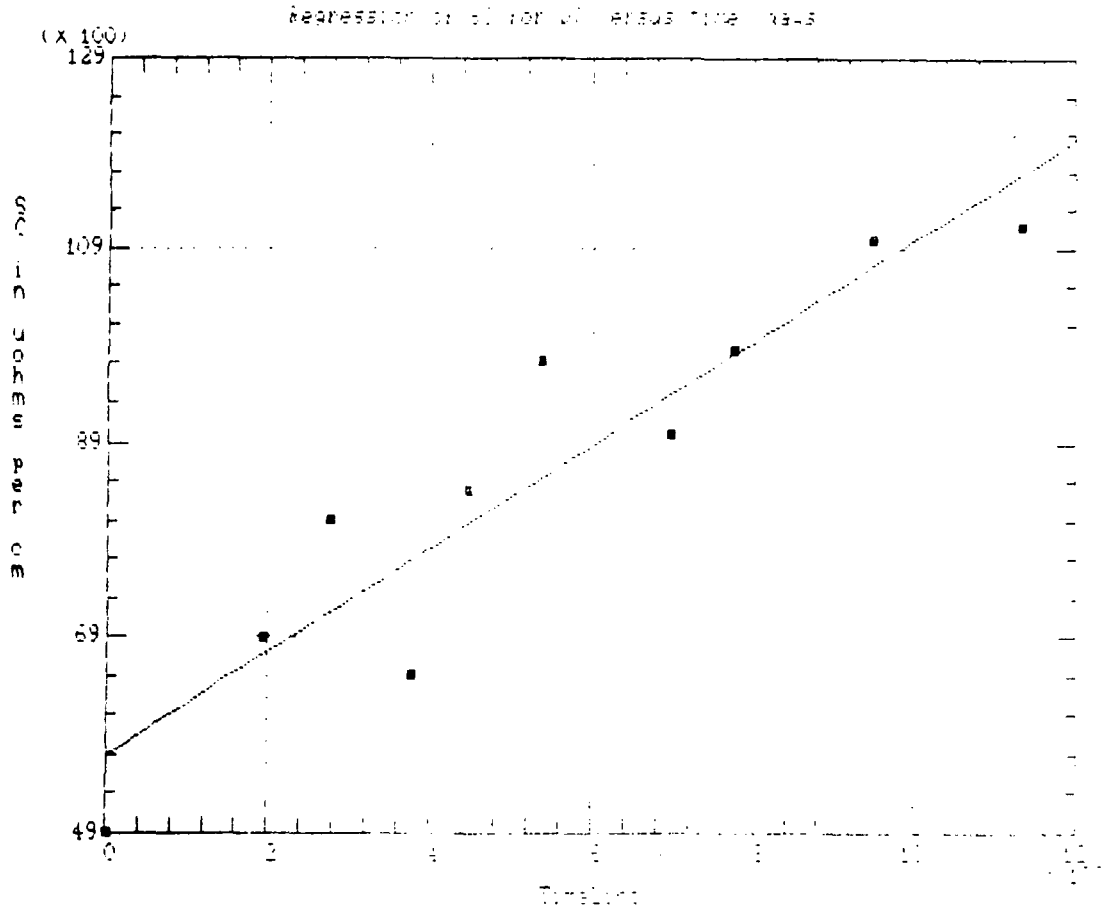

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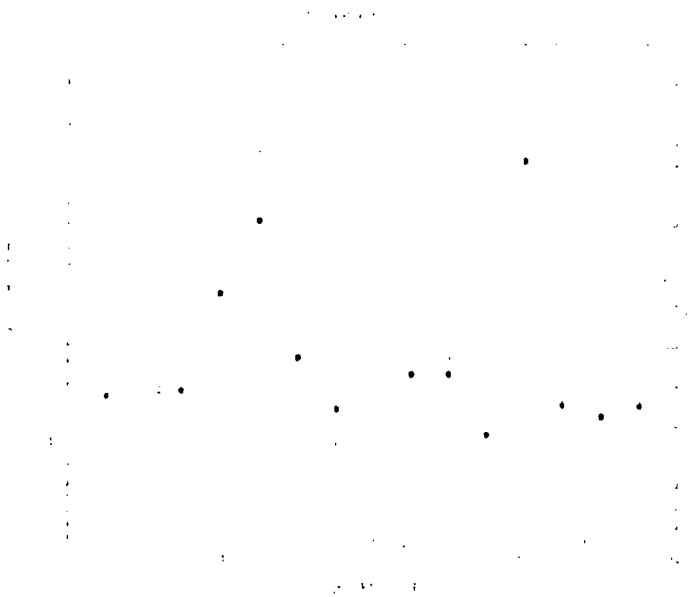
FIGURE C-11
SIMPLE LINEAR REGRESSION
OF SC IN D7 VERSUS TIME (IN DAYS)
BAYOU SORREL STATISTICS DEMONSTRATION

7/14/87 | W.O.NO. 20-08



Level	Sample size	Average	Variance	Standard deviation	Minimum
CL 1	8	59.15458.13	1260.34984	35.5013949	10.20000000
CL 2	6	61.65000000	462.93500	21.51601771	33.80000000
CL 3	6	100.6350000	1644.17215	40.5483927	47.50000000
CL 4	6	129.9500000	26391.16300	162.4535718	38.50000000
CL 5	6	75.40000000	3180.08800	34.3524889	40.50000000
CL 6	6	54.50833333	1372.49442	37.04771918	25.25000000
CL 7	6	68.51666667	964.32967	31.05365579	21.10000000
CL 8	6	68.70000000	723.84400	26.90843491	21.70000000
CL 9	6	44.46666667	1332.15067	36.49863392	10.20000000
CL 10	6	153.6483333	9534.96442	97.64771424	34.70000000
CL 11	6	55.96666667	725.21067	26.92973571	25.00000000
CL 12	6	52.08333333	1058.88967	32.54056849	19.00000000
CL 13	6	55.73333333	575.47067	23.98896971	25.10000000
TOTAL	80	75.08983333	4013.40000	63.35140899	10.20000000

Level	Maximum	Range	Median	Lower quartile	Upper quartile
CL 1	111.7333333	101.5333333	57.69333333	29.88333333	88.07500000
CL 2	82.70000000	48.90000000	66.65000000	38.00000000	82.10000000
CL 3	167.0000000	119.5000000	92.95000000	81.01000000	122.4000000
CL 4	458.0000000	419.5000000	71.50000000	40.90000000	99.30000000
CL 5	135.8000000	95.30000000	69.90000000	51.40000000	84.90000000
CL 6	127.2000000	101.9500000	41.20000000	35.50000000	56.70000000
CL 7	107.0000000	85.70000000	70.60000000	47.60000000	94.00000000
CL 8	98.60000000	76.90000000	70.40000000	61.60000000	89.50000000
CL 9	112.0000000	101.8000000	36.05000000	18.90000000	53.60000000
CL 10	289.5000000	254.8000000	160.3000000	57.29000000	219.8000000
CL 11	89.50000000	64.50000000	56.95000000	32.40000000	75.00000000
CL 12	186.6000000	87.80000000	38.80000000	33.70000000	76.20000000
CL 13	93.00000000	67.70000000	52.40000000	40.20000000	71.10000000
TOTAL	458.0000000	447.8000000	60.88.33333	39.75000000	89.69166667

Level	Interquartile range	Skewness	Kurtosis	Standardized skewness	Standardized kurtosis
CL 1	58.19166667	.01844276	1.80524893	.02129415	.6897895
CL 2	44.10000000	.3447328446	1.45528506	.3447328	-.7723574
CL 3	41.39000000	.4723792461	2.46407635	.4723792	-.26796183
CL 4	58.40000000	1.784566532	4.846812130	1.78456653	.52340615
CL 5	33.50000000	.8618257558	2.62600.361	.8618257	.18699819
CL 6	21.20000000	1.496916393	3.67561203	1.49691639	.33781601
CL 7	46.40000000	-.2981994892	2.80717969	-.2981998	.49641016
CL 8	27.90000000	.7688394516	2.68858549	.7683945	-.1557072
CL 9	14.70000000	1.123958921	3.86244716	1.12395892	.03122358
CL 10	162.5100000	.05789125	1.78897391	.0578912	-.6455138
CL 11	42.60000000	.8410488823	1.28751146	.8410488	-.8562442
CL 12	42.50000000	.7810137489	2.18813115	.7810137	.4899344
CL 13	38.90000000	.3618261681	2.18671634	.3618261	-.4466418
TOTAL	69.94166667	3.472.98685	19.48118127	12.67498087	30.84862352

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FIGURE C-8
CODE BOOK PROCEDURE
FOR WELL SPECIFIC TOC CLUSTERS
BAYOU CORPUS STATISTICS DEMONSTRATION

W.O. NO.	20.08	DATE	2/14/89

Simple Regression of TOCMgpL SELECT LocaCode EQ 3 on Timeline

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	96.965	36.764	2.6375	0.029827
Slope	-0.032452	0.058025	-0.55927	0.59129

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio
Model	1173.6314	1	1173.6314	.3128
Error	30017.798	8	3752.225	
Total (Corr.)	31191.429	9		

Correlation Coefficient = -0.19398
Stnd. Error of Est. = 61.255

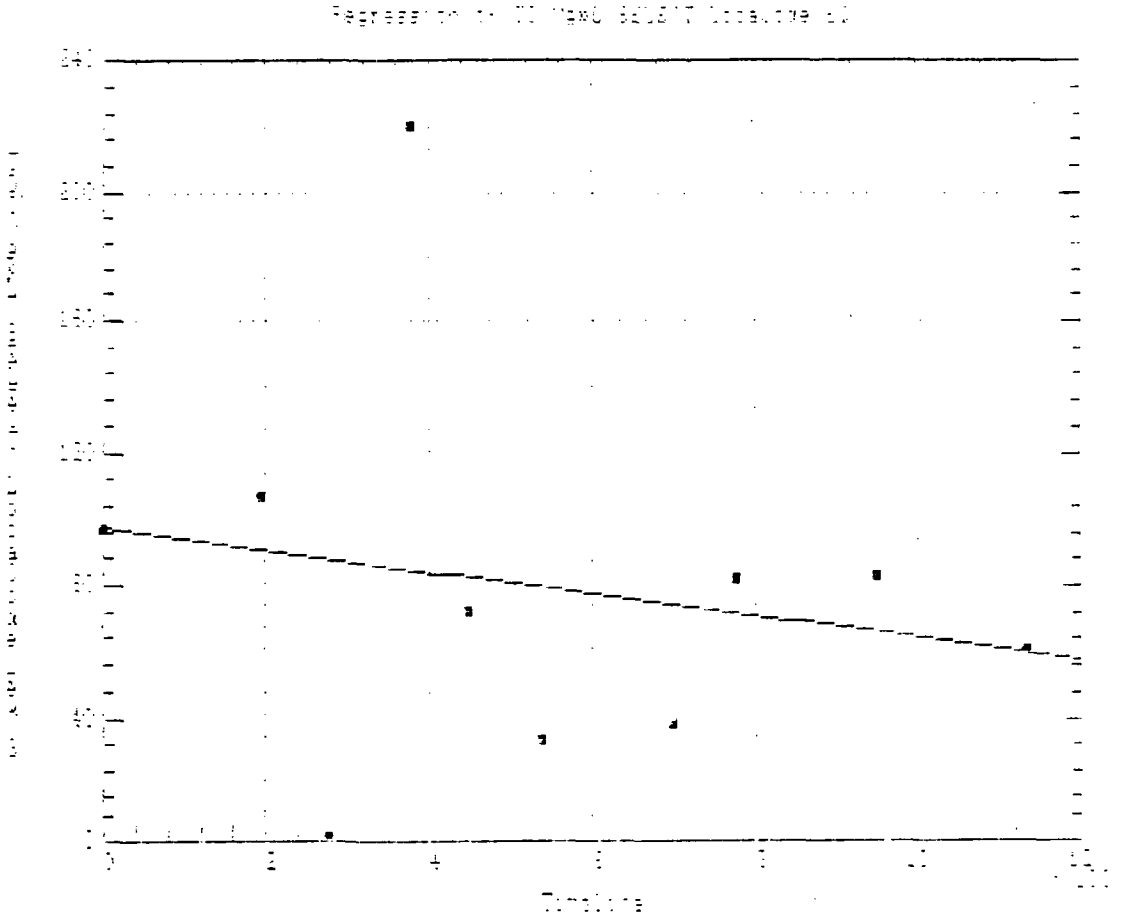

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FIGURE C-12
SIMPLE LINEAR REGRESSION
OF TOC IN D7 VERSUS TIME (IN DAYS)
BAYOU SORREL STATISTICS DEMONSTRATION

7/14/87 | W.O.NO. 20-08

[illegible] Regression of pH [illegible] Time

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	[illegible]	[illegible]	[illegible]	[illegible]
Slope	[illegible]	[illegible]	[illegible]	[illegible]

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio
Model	[illegible]	1	[illegible]	[illegible]
Error	[illegible]	8	[illegible]	
Total (Corr.)	[illegible]	9		

Correlation Coefficient = -0.20718
Stnd. Error of Est. = 0.508

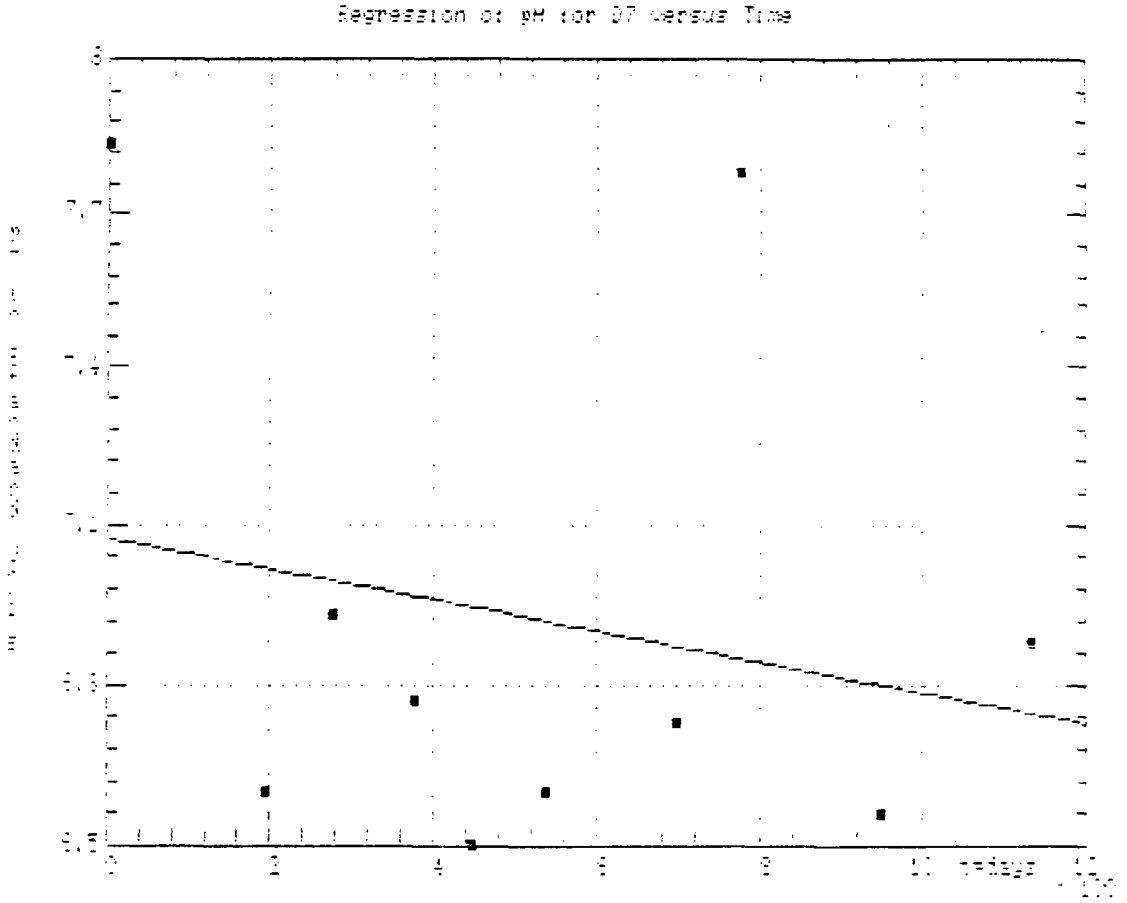

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FIGURE C-13
SIMPLE LINEAR REGRESSION
OF pH IN D7 VERSUS TIME (IN DAYS)
BAYOU SORREL STATISTICS DEMONSTRATION

7/14/87	W.O.NO. 20-08